

**SUSTAINABILITY ASSESSMENT OF LIVESTOCK
PRODUCTION SYSTEM IN RAJASTHAN**



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

**DOCTOR OF PHILOSOPHY
IN
DAIRYING
(DAIRY ECONOMICS)**

**BY
PREM CHAND
M.Sc. (Agril. Econ.)**

**DIVISION OF DAIRY ECONOMICS, STATISTICS & MANAGEMENT
NATIONAL DAIRY RESEARCH INSTITUTE
(I.C.A.R.)
KARNAL – 132001(HARYANA), INDIA
2008**

Regn. No. 1100403

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This is to certify that the thesis entitled, “**SUSTAINABILITY ASSESSMENT OF LIVESTOCK PRODUCTION SYSTEM IN RAJSTHAN**” submitted by **PREM CHAND** towards the partial fulfillment of the award of the degree of **DOCTOR OF PHILOSOPHY IN DAIRYING (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.

Dated: 19th June, 2008

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ACKNOWLEDGEMENTS

I express my deep sense of respect and gratitude to my major guide Dr. Smita Sirohi, presently working as Principal Scientist, NCAP, New Delhi, for her constant encouragement, inspiration, guidance, ingenious suggestions, incisive and constructive approach without which it would have been not only difficult, but also impossible for me to successfully complete this piece of work. I was given the all-important professional freedom, which increased my confidence and responsibility to go for the extra mile. I remain ever indebted to her for all her help and guidance to me even beyond the call of her routine duties.

My sincere gratitude to members of Advisory Committee: Dr. J.P. Dhaka, Principal Scientist, Dr. B.S. Chandel, Principal Scientist, DES&M Division, Dr. B. K. Joshi, Director, NBAGR, Dr. Jancy Gupta, Principal Scientist and Head Dairy Extension Division, Dr. D. S. Sohi, Principal Scientist and In-charge ATIC, and Dr. S. K. Sirohi, Senior Scientist, DCN Division, who have been highly helpful in my mission. Their moral support, cordial treatment, constructive criticism and practical help to me at critical time during the period of my Ph.D. programme, are worthy of loud appreciation and sincere acknowledgement. I convey my heartfelt thanks to Dr. J. P. Dhaka for promptly providing me the necessary facilities whenever I required the same

I am sincerely grateful to Dr. A. K. Shrivastava, Director, NDRI, and former Director, Dr. Sushil Kumar for providing me the necessary infrastructure facilities of the institute. I am indebted to NDRI for providing me the financial assistance in the form of fellowship, without which I could not have completed the present research project.

I express my sincere thanks to Dr. Raj Vir Singh, former Head, and other faculty members of DES&M Division for valuable suggestions in my research work.

I am thankful to Dr. Rajesh Sharma, my M.Sc. Guide and Dr. Madhu Sharma, Associate Professor, for their kind support and continuous encouragement.

I wish to thank all farmers, officers and staff of State and Central Directorate of Economics and Statistics, Department of Animal Husbandry, CSO, and Institute of Economic growth, New Delhi and local leaders of the study area. Without their help it was impossible to collect data and complete this work. I am also thankful to Scientists of NDRI and outside for their expert opinion regarding weighting of indicators of sustainability.

I have greatly benefited from the association of my seniors Dr. Rajesh, Dr. V. Sarvankumar, Dr. A.R. Khan, Sarvesh, G.L. Meena, Dr. Vikram, Anil, who have been a regular source of inspiration for me.

I enjoy the company of my batchmates Vedamurthy, Mangesh, Hemraj, Biswajeet, and Venkatesh, for moral support and comfortable stay at NDRJ, Karnal. I am specially thankful to one of my colleagues Dr. Nawla Ram for providing me the moral and financial support during the adverse conditions.

During my stay at Karnal, I always enjoyed the support of battery of juniors Feroze, Babu, Gunga, Raj Kumar, Rishi, Ambukani Hazra, Bhowmik Bipin, Gautam, Sunil, Sachin, Keshav, Jui, Debu, Madhvendra, Bitan, Susmita, Shiv Raj and all loving juniors whose names might have been left inadvertently.

My words can hardly express my feeling for inspiration, incessant encouragement, blessing and undoubted assistance of all kinds, which I derived from my parents Shri Lakhu Ram, and Mrs. Parvati Devi through which I got success at every step of my life.

My wife Amrita and son Deeptanshu were put to much hardship during my study period both, on personal and financial counts. I have the highest appreciation to them who bore the pain of my prolonged leave and still played their role beneficially. They shared love and affection with me, which enabled me to keep my mind and body together.

I am also thankful to my other family members and relatives for their continuous encouragement and support.

Last, but not the least, I appreciate with thanks the help rendered to me during the period of my study by all those whose names could not be mentioned.

Thanks to Almighty God for everything given.



(Prem Chand)

ABSTRACT

The assessment of sustainability of livestock production system in the arid-state of Rajasthan assumes greater importance in the light of the fact that livestock enterprise insulates the income of farmers against the vagaries of nature. The present study was undertaken in the state of Rajasthan, both at macro and micro level. The secondary data were collected on various parameters like, value, production and prices of various livestock products as well as socio-economic, demographic and other features. Primary data were collected for the year 2006-07 for three seasons, viz., summer, rainy and winter from 120 selected households from Jaipur district. The collected data were analyzed to assess the sustainability using two major tools namely TFP and composite encompassing indexing economic, social and ecological dimensions of the sustainability. The multiple regression analysis was carried out to know the determinants of sustainability. The total output index increased at the compound annual growth rate of 2.26 percent, marginally more than the growth in total input index (1.99%), and thereby, the TFP was very low indicating that the overall sustainability status was not very encouraging in the state. The output growth was largely input driven and shall not be sustained, if further technological improvement does not take place. The real upswing in TFP started after 1990's, which need to be maintained to improve the sustainability of livestock in the state. The mean value of Sustainable Livestock Production Index (SLPI) being 0.39, indicated that the sustainability status of livestock production is low in Rajasthan. The irrigated north-western plain zone was the top ranking zone, while southern and south-eastern plain zone was on the bottom. On the basis of weighted sustainable livestock production index (SLPI*), the values of indices were lower than SLPI indicating that zones did not perform consistently across all the three dimensions. The ecological dimension was the weakest aspect of overall sustainability status of all the zone, while economic dimension was strongest (except southern and south-eastern plain, and southern plain and Aravali hills). At district level, overall SLPI* value ranged from a low level of score (0.114) in Dungarpur district to a moderate level of 0.495 in Hanumangarh district. Categorizing the districts based on the range of SLPI* as low (<0.3), medium (0.3 to 0.5) and high (>0.5), almost half of the districts were low in their sustainability status, while remaining half performed moderately and no district fell in high category. At household level, the sustainability of dairy farming measured in terms of sustainable dairy farming index (SDFI) was 4.48, ranging from 2.86 to 5.46. More than 3/4th of the households (77.5%) had moderate SDFI score ranging from 3 to 5. Almost all the remaining households (20.8%) were having high scores suggesting that dairy farming had lineage towards sustainability. The average SDFI increased with increase in herd size category, being 4.26 on small, 4.49 on medium and 4.81 on large herd size category of households. Milk yield emerged as the most significant variable affecting sustainability followed by marketed surplus of milk, education status and area under fodder. Therefore, sustainability can be improved by improving milk yield through better technology and feeding. Good marketing facilities, extension network, vocational trainings for women are required for sustainable dairy farming.

सारांश

शुष्क राज्य राजस्थान में पशुधन उत्पादन पद्धति की स्थिरता का मूल्यांकन अत्यधिक महत्वपूर्ण है क्योंकि यह प्राकृतिक आपदाओं की स्थिति में भी किसानों को आय प्रदान करता है। वर्तमान अध्ययन राजस्थान राज्य में समष्टि एवम व्यक्ति दोनों स्तर पर किया गया है। द्वितीयक आँकड़े विभिन्न परिमाणों जैसे विभिन्न पशु उत्पादों का मूल्य, उत्पादन एवम कीमत, सामाजिक-आर्थिक, जनसंख्यात्मक एवं अन्य विशेषताओं पर एकत्रित किये गए। प्राथमिक आँकड़े तीन ऋतुओं, सर्दी, गर्मी व वर्षा के लिए जयपुर जिले के 120 चयनित परिवारों से वर्ष 2006-07 के लिए प्राप्त किये गये। एकत्रित आँकड़ों का विश्लेषण दो विधियों कुल कारक उत्पादकता एवम् स्थिरता के विभिन्न परिमाणों आर्थिक, सामाजिक एवम पारिस्थितिकीय के संयुक्त लपटाव सूचकांक की सहायता से स्थिरता मूल्यांकन हेतु किया गया। स्थिरता के निर्धारकों का निर्धारण करने हेतु बहुतायत प्रतिगमन विश्लेषण का इस्तेमाल किया गया। कुल उत्पाद सूचकांक की चक्रवृद्धि वार्षिक वृद्धि दर 2.26 प्रतिशत पायी गयी जो की कुल आगत सूचकांक की वृद्धि दर (1.99) से थोड़ी सी ज्यादा पायी गयी जिससे पता चलता है कि राजस्थान में पशुधन उत्पादन की स्थिरता बहुत ज्यादा नहीं बढ़ रही है। उत्पादन की वृद्धि आगतों पर निर्भर पायी गयी जो बिना तकनीकी सुधारों के स्थिर नहीं रह पायेगी। कुल कारक उत्पादकता में वास्तविक वृद्धि सन 1990 के बाद देखी गयी जिसे राज्य की पशुधन स्थिरता के लिये स्थिर करना आवश्यक है। स्थिर पशुधन उत्पादन सूचकांक (एस एल पी आई) औसतांक 0.39 आकां गया जो राजस्थान में पशुधन उत्पादन की स्थिरता के निम्न स्तर को दर्शाता है। सिंचित उत्तरी पश्चिमी मैदानी क्षेत्र सबसे ऊपरी स्थान, जबकि दक्षिणी व दक्षिणी पूर्वी मैदानी क्षेत्र सबसे नीचे स्थित पाये गये। भारत स्थिर पशुधन उत्पादन सूचकांक (एस एल पी आई*) की विभिन्न सूचकांक गणनाएँ एस एल पी आई की तुलना में कम पायी गयी। इससे पता चलता है कि स्थिरता के सभी परिमाणों में दृढ़ता नहीं थी। स्थिरता का पारिस्थितिकीय परिमाण सभी क्षेत्रों में सबसे कम पाया गया। जबकि आर्थिक परिमाण (दक्षिणी एवम दक्षिणी पूर्वी मैदानों क्षेत्र, और दक्षिणी मैदानी तथा अरावली पहाड़ी क्षेत्र को छोड़कर) सबसे अधिक पाया गया। जिला स्तर पर एस एल पी आई* डुंगरपुर जिले के लिये निम्न स्तर (0.114) से लेकर हनुमानगढ़ जिले के लिये मध्यम स्तर (0.495) तक देखी गयी। एस एल पी आई* के आधार पर जिलों को निम्न (<0.3) मध्यम (0.3 से 0.5) तथा उच्च (>0.5) वर्गों में बांटने पर देखा गया कि लगभग आधे जिले निम्न स्थिरता

स्तर के अन्तर्गत तथा शेष आधे जिले मध्यम स्थिरता स्तर वाले पाये गये जबकि कोई भी जिला उच्च स्थिरता स्तर वाला नहीं था। जिलों की कार्य सम्पादकता तीनों परिमाणों और उनके सूचकों के प्रति दृढ़ नहीं पायी गयी। व्यक्ति स्तर पर डेरी फार्मिंग की स्थिरता को स्थिर डेरी फार्मिंग सूचकांक (एस डी एफ आई) के रूप में मापा तो यह 4.48 था तथा 2.86 से 5.46 तक फैला हुआ था। तीन चौथाई से भी ज्यादा किसान परिवारों (77.5%) का एस डी एफ आई मध्यम स्तर का था जिसका फेलाव 3 से 5 तक था। लगभग शेष किसान परिवारों (20.8%) का स्तर उच्च था जिससे डेरी फार्मिंग का स्थिरता से जुड़ाव दर्शाता है। औसत एस डी एफ आई विभिन्न पशु झुण्ड आकारों के साथ लघु पशु झुण्ड आकार में 4.01 से, मध्यम पशु झुण्ड आकार में 4.49 तथा वृद्ध पशु झुण्ड आकार में 4.81 तक बढ़ता हुआ पाया गया। पशु दुग्ध उत्पादकता स्थिरता की प्रमाणित करने वाला सबसे सार्थक चर पाया गया और उसके बाद बाजार आधिक्य, शिक्षा का स्तर तथा चारे की उपलवधता सार्थक चर के रूप में पहचाने गये। अतः दुग्ध उत्पादकता बढ़ाने हेतु तकनीकी एवम अच्छी आहार व्यवस्था होनी चाहिए ताकि स्थिरता बढ़ाई जा सके। विपणन बुनियादी सुविधाएँ भी दुग्ध विपणन एवम किसानों को अच्छे दाम हेतु उपलब्ध कराई जानी चाहिए।

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1. INTRODUCTION

The development strategies for sustainable agricultural production are fairly recent in origin. The chain of development strategies started with the concept of use of science and technology as the main bull work to move the food production cycle forward, to meet the food need of ever growing human population in the world. However, when the outcome of agricultural development started exhibiting bans coupled with boons; the concerns emerged that present development should not be at the expense of future generation. The link of sustainability was hence added to the chain of development strategies.

1.1 CONCEPT OF SUSTAINABILITY

The genesis of sustainability in development can be treated to the first UN Conference on Human Development held in 1972 at Stockholm, when global consciousness on ecology, environment and poverty was brought to the centre stage of development. However, a conceptual breakthrough on sustainable development came in June 1992, when it was adopted as Agenda 21 during the UN Conference on Environment and Development, held at Rio de Janeiro. Since then, the expression “sustainable development’ has been receiving increasing attention and has become inevitable in all the development discourses.

The word ‘sustainable’ originated from the Latin word ‘sustinaise’, which means ‘hold-up’. The term sustainable development, being quite vague, many developmental experts and researchers perceived it differently and defined it in their own way (Michael, 1991). Reiterating on the system resilience and stability, Conwey (1985) defined sustainability as the ability of a system to maintain productivity inspite of major disturbance caused by intensive stress or large perturbations.

The most comprehensive and acceptable definition of sustainable development is provided by the Brundtland Commission (1987). The Commission states that the “*humanity has the ability to make development sustainable to ensure that it meets the needs of the present generation without compromising the ability of future generations to meet their own needs*” (WEDC, 1987). Here, ‘needs’ refers to essential requirements of world’s poor, and ‘ability’ imposes ‘limits’ to production frontiers and ability of the environment to produce. In very simple terms, the concept can be said to combine two basic notions: **economic development and ecological sustainability**. If a system or an activity fails to include these two notions, it does not represent sustainable development.

Sustainability has also been described as ‘robustness’ or the propensity of the system to withstand collapse under stress. The precise meaning of terms such as ‘sustainable resource usage’, ‘sustainable growth’ and ‘sustainable development’ has so far proved elusive. Intuitively, sustainability arguments seem to be stressing the need to view environmental protection and continuing economic growth (in terms of growth of per capita real incomes over time) as mutually compatible and not necessarily conflicting objectives. Sustainability could therefore imply compatibility with natural resource base, limitations and biospherical waste assimilation capacities, and require a search for bioeconomic equilibria” (Turner, 1988).

Costanza defined “Sustainability: An ecological system is healthy and free from ‘distress syndrome’ if it is stable and sustainable, that is, if it is active and maintains its structure (organization) function (vigor) and autonomy over time and is resilient to stress” (Costanza, 1994).

1.2 WHAT IS SUSTAINABLE AGRICULTURE?

Sustainability of agriculture has also been interpreted in a number of ways in the recent literature. Organic methods of farming or ‘permanent agriculture’ which respect the integrity of the soil and related ecological

systems have been referred to as 'sustainable'. Among the leading writers on the subject, Conway (1985), maintained that an agricultural system that can overcome a stress, defined as a discontinuity in the situation to which it is subjected, can be referred as sustainable. Parikh and Ghosh (1991), considered soil in particular to be an important resource base and think it should be treated as the reference point for defining sustainability. Jodha (1991), treated sustainability as a characteristic of the agricultural system: "It is the ability of the system to maintain certain well defined level of performance over time, and if required to enhance the same through linkages with other systems without damaging the ecological integrity of the system." Around the theme of this definition, Chopra (1993), Devendra (1993), Nadkarni (1993) and Swaminathan (1997) interpreted the sustainable agricultural development as "the development strategy that enables the production system to maintain certain well-defined level of performance and non-negative growth overtime, without damaging the ecological integrity of the system". The FAO (1991), on the other hand, defined more comprehensively sustainable agriculture as *"The management and conservation of resource base and the orientation of technological and institutional changes in such a manner as to ensure the attended and continual satisfaction of human need for present and future generations. Such development is environmentally non-degrading, technically appropriate, economically viable and socially acceptable."*

It is well recognized that crops and livestock are integral and inseparable activities hence, sustainable development of one cannot be isolated with sustainable development of other. Livestock play an important role in ensuring sustainability of agriculture production through providing draft animal power for agricultural operations and rural transport and organic manure so essential for maintaining the soil fertility. It provides self-employment throughout the year to both men and women in family. Therefore, sustainability issues in livestock sector are equally important in Indian context where more than ¼ of the agricultural output comes from livestock sector.

1.3 SUSTAINABLE LIVESTOCK PRODUCTION : OPERATIONAL DEFINITION

Sustainable livestock production aims at maintaining high producing and economic yielding animals per unit of time and inputs on long term basis with least deterioration in natural resources, which contribute life support system for agriculture and animal production and with least contribution to environmental degradation.

At the enterprise level say dairy farm, the sustainability might be considered to be in two ways:

- The development of an enterprise that contribute to societal sustainability; or
- The development of an enterprise that fulfils the conditions for sustainability for the enterprise itself.

Many publications about the sustainability of sustainability of farmers have implicitly used the first meaning of sustainability at the enterprise level. In defining business practices that enable a sustainable use of resources at the societal level there is possibility of overlooking that an enterprise itself can also be developed in a sustainable or unsustainable way.

The sustainable development of an enterprise, following the second understanding, would imply that the enterprise is managed in a way that allows the next generation to take it over. Thus, Mann and Gazzarin (2004) define sustainable development of an enterprise as follows :

“To manage an enterprise in a way that keeps it profitable for the current generation and also for the next generation say, 30 years ahead.”

A word of caution, however, needs to be sounded here about the implications of this definition for intra-family or inter-family succession. Although, the probability of finding a successor for a sustainable farm is higher than others, yet intra-family as well as inter-family succession are both

dependent on a large range of factors, including random ones. Hence, this definition of sustainable farm should not be interpreted as that of a farm ready for a willing successor to take over.

1.4 SUSTAINABILITY CONCERNS FOR LIVESTOCK DEVELOPMENT IN INDIA

The population of India is over 1.02 billion. The expected average annual growth in population is 1.8 percent between 2000-2010 and 1.6 percent between 2010-2020. Considering this trend, the population would be around 1.3 billion by 2021 (Economic Survey, 2004-05). Increasing the production of agro-based products to cater to the needs of this burgeoning population is a daunting task. For instance, to meet the projected demand of 172 million tones for milk by 2020, the growth in milk production should be sustained at the current level of 4.06 percent in the next 15 years.

In the scenario of low livestock productivity, high growth in demand for animal foods leads to increase in livestock population. As livestock are owned by weaker-sections who have little to invest in improved technologies for better production, they try to improve their income by increasing the number of animals in the herd. This adds to the population of low producing animals in the country. Unproductive animals especially cattle and buffaloes continue to live in spite of having completed their economic life due to Indian humanism, and compete with productive cattle and animals of other species thus adding to feed deficit and also to degradation of land resources.

The gap between nutrient requirement and availability has been estimated at 46.2 percent DCP and 44.2 percent with regard to TDN for bovine population of the country (Jain *et al.*, 1996). The area under fodder crops has decreased from 4.2 percent to 3.3 percent. Further, the cultivated land in India is almost stabilized at 140-142 million hectares and further area increase is not visualized. In order to increase production further, there is no other option except to lay greater emphasis on increasing productivity through precision farming by conserving natural resources. The first green revolution

has led to second generation problems, such as depletion of soil nutrients and water resources, creation of salinity and water logging, resurgence of pests and diseases, increased environmental pollution, factor productivity decline, etc. With the increase of these problems, the availability of animal feed is affected. This is a major constraint in sustained increase animal productivity in India.

The traditional package of practices for breeding, feeding, housing, management and health usually followed by farmers for rearing dairy animals, particularly of high production potentials do not result in further enhancing and sustaining the productivity of animals. There are several gaps/constraints, which may affect the production of indigenous and crossbred cattle and buffaloes and make them unsustainable in long run.

The inability of organized sector to provide significant employment and rising population is leading to increasing reliance of the growing work force on the unorganized sector of which agricultural sector account for major share. Livestock and dairy development can form a major instrumentality for overcoming unemployment as employment opportunities in animal husbandry and dairying are higher than in crop husbandry and play important role in ensuring sustainability of agricultural production.

In the long-term vision though traditional mixed crop/livestock farming system will continue to be a dominant system in India for many decades to come, the switch over to specialization or commercialization cannot be ruled out. The valid question is whether such large scale specialized system will promote global welfare including environment, men and animals. Thus, it is essential to assess the sustainability and its relevance in animal production system, as it is the vital source of nutrients, provides animal draft power and manure for agriculture and gainful employment to rural population.

1.5 STATEMENT OF THE PROBLEM

Though the topic of sustainability and sustainable production has been engaging the attention of researchers in our country, for some years very few

researchers have attempted to conduct research on this subject in crop production and much fewer in livestock particularly, the empirical work on the subject is extremely limited.

The assessment of the sustainability of livestock production system in the arid state of Rajasthan assumes greater importance in the light of the fact that livestock enterprise insulates the income of farmers against the vagaries of nature and resulting frequent droughts in the state. The dominant role of livestock in the agrarian economy of Rajasthan is evident from the fact that the share of livestock sector in total value of output from agricultural and allied activities is 48 percent while corresponding figure for India is 28 percent. Livestock sector contributes to the tune of about 19 percent to State Domestic Product and this is expected to double by the year 2020. Rajasthan produces around 13 percent of country's milk output, 40 percent of country's meat and 42 percent of wool production. The major share of income from animal husbandry sector in the state comes from dairy farming. It provides jobs to millions and supplements the income of the rural masses in general, for their sustenance.

Unfortunately the agricultural sustainability status of Rajasthan is quite poor among the Northern states of India (Saleth, 1993). Sixty percent of area in the state falls within the fragile resources region of Thar Desert. The region has low input absorption capacity, and is highly susceptible to various forms of resource degradation including increased salinity (of both soil and ground water) and deepening of water level. Decline in overall biomass availability, substitution of cattle (and camels in arid areas by sheep and goats, and extension of cropping to sub marginal area have led to increased dependence on public relief and increased seasonal migration to other areas (Jodha, 1986, 1988). The shrinking of common grazing land over a period of time has widened the gap between demand and supply of fodder.

Low productivity of all species, inspite of large number of livestock, is a major development constraint facing the sector. Almost 60 percent of cattle and about 80 percent of buffaloes are non-descriptive and have low milk and

work output. Thus, the inhospitable climate of arid ecosystem and impoverished fragile resource, coupled with scare water resources, and low productivity of animals make sustainability a very important issue in Rajasthan.

There are several key questions pertaining to sustainability, which remain unanswered in the literature. The important aspects of the issue that need to be addressed are, extent of sustainability of the livestock production system in the state, the weakness and strength of the major livestock activity, viz., dairy farming from the long run perspective, etc.

The results of the study are important in drawing policy implications for improve the sustainability and if the threatened, same is observed to be suggest ways and means to reverse the damages.

The present study “**Sustainability Assessment of Livestock Production System in Rajasthan**” was endeavored to assess the sustainability of livestock production system in Rajasthan with the following specific objectives:

Objectives:

- (I) To measure the Total Factor Productivity (TFP) growth in livestock sector in Rajasthan.
- (II) To examine the economic, social and ecological sustainability of livestock production across various agro-climatic zones and districts of the state.
- (III) To evaluate the socio-economic and ecological dimensions of sustainable dairy farming on sample households.
- (IV) To study the factors affecting sustainability of dairy farming in the study area.

1.6 ORGANIZATION OF THE STUDY

The present study has been organized in six Chapters. Chapter one pertains to introduction, which conceptualizes the term sustainability. The second Chapter reviews the literature that was referred in connection with the

present study. The analytical tools and techniques used are described in the Chapter of Methodology, while background of the study area for meaningful interpretation of the results is presented in the Chapter Profile of the study area. The findings of the present investigation are discussed in fifth Chapter, i.e., Results and Discussion and last chapter summarises and concludes the study drawing policy implications for sustainable livestock production in Rajasthan.

2. REVIEW OF LITERATURE

The earlier studies directly or indirectly related to the assessment of the sustainability of livestock and agriculture production in India and the factors affecting the same, are reviewed to crystallize the methodology of present study and enrich the discussion of its results with their findings. The relevant review of literature has been presented in three sub-sections:

- 2.1 Sustainability Status of Livestock Production in India
- 2.2 Sustainability of Indian Agriculture
- 2.3 Determinants of Sustainability

At the end, the methodological approach and robust inferences that emerged out of the studies are summarised.

2.1 SUSTAINABILITY STATUS OF LIVESTOCK PRODUCTION IN INDIA

The estimation of total factor productivity (TFP) growth is one of the widely used analytical technique for drawing inferences about the sustainability of the production system. The technique has been widely used in Indian context to measure the sustainability of crop production or farming system (Ehui and Spencer, 1990; Whitakar and Lalitha, 1993; Kumar *et al.*, 1998; Kumar and Mittal, 2006; Chandel, 2007). However, sustainability oriented analysis of TFP has not been made in the livestock sector although a few studies have analyzed the TFP of livestock production system at all-India and State levels.

One such comprehensive study (Kumar and Pandey, 1999) at all India level, found that livestock output grew at the rate of 2.6 percent per year over the period 1950-51 to 1995-96. The input index increased by 1.8 percent per year and TFP grew at about 0.8 percent, implying that technological change contributed about 30 percent to the overall growth over the past 45 years. The

period-wise results showed the very interesting pattern with almost negligible TFP growth during 1950-51 to 1970-71 followed by marginal improvement during 1970's and a real swing after the 1980s. During 1980-81 to 1995-96, the TFP growth of livestock sector was nearly 1.8 percent, contributing 45 percent to the total output growth.

Although, the inferences in the above study were not drawn from the perspective of sustainability of livestock production system, but the non-negative and accelerating TFP growth suggests a general trend towards improvement in the sustainability of the system over the years.

Another more updated study for the period 1981 to 2001, at the all India level by Avila and Evenson (2004) reported TFP growth of over two and half percent per annum in livestock, thus, further substantiating the empirical evidence of the systems leaning towards sustainability.

The study by Fan *et al.* (1999), analyzing the TFP growth in the Indian crop and livestock sector, taken together, differs in the magnitude of TFP growth, partly, due to differences in context of period covered and partly, due to the database used but, broadly reports positive trend in TFP particularly, during the eighties.

At the state level, Elumalai and Pandey (2004) conducted study in Haryana and measured technological change in the livestock sector across districts, regions and state as a whole, during the period 1970 to 1998-99. Over the period of the study, the livestock output grew at the rate of 2.42 percent while, input index increased by 1.83 percent and TFP grew at 0.65 percent. The TFP growth rates for the different periods were on the lower side as compared to all-India level growth rate reported by Kumar and Pandey (1999). The TFP growth rate was 0.6 percent per annum during the period 1970-71 to 1978-79, which moderately increased to 0.7 percent during 1979-80 to 1988-89 and sustained 1.0 percent per annum growth rate during period 1989-90 to 1998-99. Almost similar trends in TFP growth existed across districts during different periods of study. As in case of all-India level study by Kumar and Pandey (1999), this state level study also does not interpret the

results of TFP from the perspective of sustainability of livestock production in Haryana. However, it pointed out that there is still scope for the exploitation of modern technologies across the districts in the state, which may be done by developing livestock technologies, revamping livestock production and marketing policy prescriptions by the state policy planners and disseminating such policies to the farmers.

At the micro level TFP was used by Singh (1996) for assessing sustainability of non-descript cows, crossbred cows and buffaloes and major crops in the green revolution belt of India for the period 1977-78, 1984-85 and 1990-91. The TFP in almost all the selected enterprises of the farming system indicated an increasing trend over the period showing sustainability of these enterprises in the area. During 1977-78 to 1990-91, the total factor productivity index increased from 0.66 to 0.77 in case of non-descriptive cows, from 0.93 to 1.12 in buffalo, 1.65 to 1.67 in paddy and 1.35 to 1.60 in case of wheat. A marginal decline in TFP index of crossbred cows during this period was suggested to be attributed to sale of large number of good quality of crossbred cows to other states due to unremunerative prices of crossbred cow milk.

Besides the sustainability of livestock production from a micro perspective using TFP approach, Singh (1996) also carried out a macro analysis of growth in animal productivity, relative change in per capita production of milk and meat production for the period 1983 to 1994, to look into the issue of sustainability for Asia-Pacific region as a whole. Based on the declining compound annual growth rate of livestock output, productivity and per capita availability, he inferred that trend toward unsustainability existed in most of the countries of the region. However, India reported positive and higher growth rate in productivity and production of livestock. The per capita per day production of milk and meat increased by around 27 percent and 200 percent, respectively, in 1993 over 1985.

In a state level study in India, Dixit (1999) also drew upon trends in milk production, compositional changes in bovine population, cost and returns, and

instability index of milk production to make an assessment of the sustainability of bovine economy in southern state of Karnataka. The results of the study showed that the bovine population was changing in favour of females and increased from around 50 percent in 1977 to 67.45 percent in 1997 in case of indigenous cattle, from 85.47 percent in 1983 to over 95 percent 1997 in case of crossbred cattle and from 85 percent to 94 percent from 1977 to 1997 in case of buffalo. Further, he pointed out that species composition changed in favour of crossbred cattle and buffaloes and was a welcome signal toward sustainability of bovine stock in the state. The milk production and productivity increased at the compound growth rate of 5.97 and 4.52 percent per annum, respectively, during the period 1984 to 1996 indicating favorable aspect to achieving sustainable milk production. The author contented that though the net return was low from buffalo and even negative from local cow, it should not be interpreted the unsustainability of bovine, because about 60 percent of resources were either drawn from the farm owned sources that have less opportunity cost or from communal resources, for which society bears the cost. He pointed out that high growth rate co-existing with high instability of milk production was a matter of concern and measures to ensure sustainability were required.

Singh and Raman (1994) followed a different approach to find out sustainable livestock population that the hill system and fodder supply in Western Himalayas can sustain. They used population dynamics and herd composition and worked out the sustainable animal number in cow equivalent units. The surplus livestock population increased from 2096 thousand in 1972 to around 2468 thousand in 1987 in the state. They found a surplus stock of 55 percent. The surplus livestock was found to produce environmental problems in terms of soil erosion, gully formulation and thinning of forest. Study suggested the need to delimit livestock number in the state for sustainable livestock production.

A few studies have focused on ascertaining the sustainability of dairy farming practices in the country. A comparative study in Bihar and Haryana was conducted by Yadav (2005) to examine the sustainability of scientific crop

cultivation and dairy practices as perceived by the farmers and subject matter specialists. He scored the perception of farmers regarding sustainability of different practices adopted by them and also took the opinion of experts regarding the extent of sustainability of practices adopted by the farmers. He found that among the scientific cattle husbandry practices studied feeding of green fodder was considered to be most sustainable practice for dairy production by the farmers and expert respondents in both the study areas. Surprisingly, the vaccination of animals in case of Bihar and artificial insemination in Haryana were reported as least sustainable practice. The least scores accorded to these important practices speak volumes about the poor outreach of effective healthcare and breeding services to the dairy farmers. Among the buffalo management also, green fodder was envisaged to be most sustainable and AI least sustainable in both Bihar and Haryana.

A similar study carried out in Lower Gangetic Plain zone of India by Chakarvarti (2006) brought out somewhat different results. On a 100-point scale, the experts opined AI to be most sustainable with sustainability index (SI) of 86.15, followed by green fodder cultivation, deworming and tick control. The farmers ranked green fodder cultivation, vaccination of animals, AI, tick control and de-worming in the decreasing order of perceived sustainability.

2.2 SUSTAINABILITY OF AGRICULTURAL PRODUCTION IN INDIA

It emerges from the previous section that the studies on the quantitative aspects of livestock production sustainability are limited in number, scope and coverage. However, as livestock production is carried out in mixed farming set-up, it is also important to review studies related to sustainability of agriculture production. This exercise is useful from two perspectives: one, it would give a broad dimension for understanding the synergy between sustainability of livestock and crop production, and second, throw light on the methodological approaches used in the literature for sustainability assessment of agricultural production in India.

Rosegrant and Evenson (1992) studied the TFP of crop sector for the period 1957 to 1985 and reported positive growth of the same in India. However, there were decadal variations in the rate of growth largely due to

abnormal weather conditions. TFP grew at modest annual rate of 0.81 percent during 1957-65, increased to 1.22 percent with the inception of Green Revolution in the next decade (1965-75), but could not sustain the momentum in the subsequent decades due to severe drought in 1979 and declined to 1.00 percent during 1975-85. In a later study, extending the crop coverage and excluding the data for abnormal years, the same authors (Rosegrant and Evenson, 1995) came up with larger estimates of TFP for the similar time period, indicating the adverse impact of drought years for sustainability of crop sector in India.

In the period after the late eighties, the sustainability of agriculture came under severe pressure as can be inferred from the performance analysis of Indian agriculture carried out by various studies. Kalirajan and Shand (1997) explored the performance of the Indian agricultural sector during the immediate pre-reform period of the 1980s, using state-level data for the period 1980-90 for 15 of the 25 states and Union territories in India (which account for 95% of national food grain production and 85% of national agricultural output). The results showed that 11 out of 15 states showed substantial positive, but declining, contributions to growth in total factor productivity (TFP) during the period. The contribution of TFP growth was negative throughout in the other four states. The contribution of technology to output growth declined substantially, particularly from 1988-90 and technical efficiency increased only slowly.

Based on the long run TFP trends, Kumar and Mittal (2006) also concluded existence of a threat to sustainability of crops during the nineties. The rate of positive TFP growth fell drastically in the period 1986-2000 over 1971-86 for wheat and coarse cereals; stagnated for oilseeds and turned negative to pulses, fibers, sugarcane and vegetable crops. Paddy was the only crop where TFP growth accelerated in the later period compared to the former period, but in that too, a declining trend was discernible in northern India, comprising the states of Punjab, Haryana, UP and Himachal Pradesh. In Rajasthan, during 1971-86, the TFP stagnated for maize, moong and gram; increased slowly at a rate of less than 2 percent for jowar, bajra and wheat,

and registered a growth of over 2 percent only for paddy, rapeseed and mustard. After 1986, the TFP growth picked up only for pearl millet while for rest of the crops, either it stagnated, showed slow growth or declined.

The empirical evidence from prime agricultural region of the country also show some disquieting trends in the sustainability of crop production. The TFP growth in rice-wheat cropping system in Indo-Gangetic region became almost negative in the period 1985 to 1992 after registering an increase of 2.9 percent during 1976-1985 (Kumar *et al.*, 1998). The situation had been particularly grim in Uttar Pradesh where the TFP growth was negative (-1.2%) during the later period.

Another study in the Indo-Gangetic plain region covering the period 1980-81 to 1996-97 also found that the output growth in the Upper Gangetic Plains (UGP) and Middle Gangetic Plains (MGP) was input-based, while, in the Lower Gangetic Plains (LGP), it was technology-based (Kumar *et al.*, 2004). The analysis has confirmed that contribution of TFP growth to output growth had started declining and was, in fact, showing a tendency of further deterioration in the process. Productivity growth, which picked up during the early-1980s, could not sustain during 1990s showing clear signs of unsustainability.

The sustainability of Indian agriculture has also been evaluated using tools and techniques other than TFP growth.

Bhatia (2006) analyzed the pattern of development and trends in productivity and profitability to examine if Indian agriculture met the requirement of sustainable development. On the basis of over 2 percent rate of agricultural production during the four decades of development (1950-1990), the study concluded that agricultural growth and development during this period was socially sustainable as it was high enough to keep pace with the increasing demand. However, after 1990-91, there was deceleration in the rate of production and yield of major cereals, sugarcane, jute, cotton, and potato. Therefore, the researcher pointed out that the declining growth of

cereal production would not be able to meet the demand of the society and hence its technology could not be deemed as socially sustainable.

Joshi and Tyagi (1991) examined sustainability of existing farming systems in Punjab and Haryana by using compound annual growth rates of area, yield and production of rice, wheat and sugarcane and exploitation of ground water during the green revolution period (1972-80) and post green revolution period (1980-87). They found that growth rate of the crops have slowed down during the post-green revolution period which posed a disturbing trend on the sustainability of agricultural production in these states. In good water quality regions, the existing production levels were maintained by over-exploitation of ground water. Contrary to this, the poor water quality regions were under utilizing ground water and deteriorating the soil health by salinity and water logging. Both the phenomena were undesirable and threatened the production and ecological sustainability.

Chand and Haque (1997) based on the stagnating quinquennial average yield of wheat and rice during 1970-1994 in Punjab, Haryana and UP also opined that the trends revealed an imminent threat to the sustainability of rice wheat cropping system in India in general and in these states, in particular.

In a more recent study, Jha (2004) evaluated the sustainability of Indian greenbelt using both, the performance based and resource-based indicators of sustainability. The performance based sustainability indicators included, growth, stability, total factor productivity and vulnerability, while the resource based sustainability indicators directly included changes in the status of the natural resources (soil and ground water) reflecting the gap between the use and regeneration of resources during the reference period. The study found that agricultural prosperity of the region was largely associated with the area under rice and wheat crops. Analysis of factor productivity showed decreasing trend in productivity of these crops and resource degradation appeared to be the reason behind this disconcerting trend. The resource base indicators of sustainability, manifested that the rate

of use of ground water and soil micro-nutrients had been greater than the combined affect of resource regeneration and artificial application in the region. This degradation affected present rate of growth and had profound implications for the future sustainability of agriculture.

Indexing of variables representing environmental and socio-economic dimensions of agriculture sustainability is another approach followed in the literature to examine the relative sustainability status of agro-climatic zones / states / districts and farmers.

Saleth and Swaminathan (1992) developed the Sustainable Livelihood Security Index (SLSI) using the methodology of Human Development Index (HDI) of United Nations Development Programme (UNDP). The SLSI was the integration of ecological, economic and social dimensions; with two variables to represent each component, viz., forest cover (%), and net sown area (%) for ecological; land productivity, and area under cereals (%) for economic efficiency; people above poverty line (%) and literacy rate (%) for social equity. The SLSI ranking showed that the region having the best conditions for agricultural sustainability was the Western Coast (Kerala state, Goa, and the advanced enclaves of Karnataka and Maharashtra) with its value 0.80, followed by the Trans-Gangetic region (Punjab and Haryana) with SLSI, 0.67, where the green revolution technology had its greatest impact as compared to the other regions of India. On the other hand, the regions having the least desirable conditions for agricultural sustainability were the Western Dryland (desert areas of Rajasthan) and the Eastern Plateau (mining and tribal belts of Bihar, Madhya Pradesh, and Orissa states) regions. The regions with the higher (lower) SLSI ranks were those often described as advanced (backward) using other economic and social indicators. The authors suggested that although all the three dimensions of sustainability need to be strengthened to improve agricultural sustainability, the relative emphasis to be given to the three dimensions need not necessarily be the same.

Later, using additional variables, Saleth (1993) applied SLSI to evaluate the relative sustainability status of 80 agro-climatic sub-zones of India. The overall sustainability status in terms of SLSI* (weighted index) showed a wide

range from 0.623 in south coastal Andhra zone to 0.147 in western arid region of Rajasthan. The performance of the zones was not consistent across the three dimensions. The variability was observed to be more in ecological and economic aspects than equity aspect. Out of 80 sample regions, only about one third regions, located mostly in Madhya Pradesh, Andhra Pradesh, Kerala, Orissa and West Bengal had an SLSI of above 0.5. About 1/3rd zones, located mostly in the arid and hilly tracts of Bihar, Rajasthan, Madhya Pradesh, Uttar Pradesh, Gujarat and Tamil Naddu had an SLSI lower than 0.3, required top priority in agricultural investment. Among them, western arid region of Rajasthan, Jhabua hills and Keymore plateau regions of Madhya Pradesh, all five zones of Bihar, the central plateau of Maharashtra and eastern plain of Uttar Pradesh required immediate policy attention.

The SLSI was used by Yadav and Rai, (2001) covering the same indicators as taken by Saleth (1993) to evaluate the sustainability of agriculture in Haryana across districts. They observed that the agriculture system in Haryana showed wider variation across districts in their ecological and social aspects than in economic aspects. The performance was not consistent across the three aspects of sustainable development of agriculture. They suggested that adjustment/changes, e.g., diversification, crop rotations in crop plants must be facilitated in order to achieve a balanced crop-mix to make progress towards profitable and environmentally sustainable production system.

Another state specific study, using SLSI was made by Sen and Hatai (2007) to examine the relative agricultural sustainability across districts of Orissa. They found that the values of Ecological Security Index (ESI), Economic Efficiency Index (EEI) and Social Equity Index (SEI) varied from 0.68 to 0.141, 0.75 to 0.075 and 0.701 to 0.209, respectively, indicating that the agricultural systems of all districts of Orissa displayed wide variations in their ecological, economic and social equity aspects. The overall performance of the districts showed low values of both, SLSI and SLSI*. In only eight districts (about 1/4th) out of 30 districts in Orissa, the index was above 0.5,

while thirteen districts were having an SLSI* lower than 0.4. Moreover, many of the districts of coastal Orissa performed better in agricultural sustainability in comparison to the districts of western Orissa, as a whole.

Similar observations were made by Bhati and Sen (1997) regarding the overall performance of districts in Bihar in terms of their relative Sustainable Livelihood Security Index (SLSI*). In only about 1/4th of the 40 districts of the state SLSI* was above 0.5 and in more than half of the total districts SLSI* was lower than 0.4. In general, most of the districts of south Bihar performed better in agricultural sustainability status in comparison to the districts of north Bihar.

Stressing on agricultural diversification in favour of livestock economy, Hatai *et al.* (2006) evaluated the sustainable agricultural development for rural livelihood perspective across districts of Orissa. Sustainable Agricultural Development Index (SADI) was constructed using seven agricultural development indicators to establish inter-district priority for the allocation of resources and upliftment of the rural poor. The districts with the lower SADI ranks were described as agriculturally backward, while those with the better SADI ranks were considered advanced in agriculture. It was argued that districts with poor condition of agriculture (having value of SADI <0.4) should be accorded top priority in agricultural development.

An index was developed by Gowda and Jayaramaiah (1998) to measure the sustainability of rice production systems at a farm level by identifying nine indicators, grouped under the three dimensions of sustainability namely, ecological, economic and social. The index was applied to rice farmers sampled from irrigated, rainfed lowland, rainfed upland and tankfed rice systems in Karnataka. Although, significant differences were found among the four systems, each system had positive and negative attributes. Rainfed lowland production was the best system followed by irrigated production. The rainfed upland system was the least sustainable. The rainfed lowland system did not dominate in any of the dimensions of

sustainability but emerged as the best in a composite index. This confirms the general agreement that sustainable farming avoids maximising any single outcome variable, but instead balances all the dimensions of sustainability.

Farmers sustainability index (FSI) was developed by Bonny and Vijayaragavan (2001) to measure the adoption of sustainable practice by traditional rice growers of Kuttanad agro-ecosystem in Kerala. Based on the mean FSI scores of each group, the groups were named as conventional and sustainable. The results indicate a wide range between the mean FSI scores of conventional (23.93) and sustainable (70.06) adopter categories. The conventional and sustainable adopter categories maintained significantly distinct position on all selected practices and also, on the overall total FSI scores. It provides that the conventional and sustainable groups acted differently on all production practices in concordance with their technological allegiance.

2.3 DETERMINANTS OF SUSTAINABILITY

The sustainability of biological production systems like livestock and crop is affected by a large number of factors.

There are several studies that have highlighted the issues that are important for sustainable animal production and throw light on the factors affecting sustainable dairy farming. Although these studies do not follow any quantitative approach to assess the sustainability status of livestock production system in the country and its determinants, nevertheless, they delineate the breeding, feeding and management factors affecting the sustainability of livestock production in general, and dairy farming, in particular. The important determinants of sustainability are: superior germplasm, breeding and animal health care facilities, (Bhat and Taneja, 1998; Joshi, 2004; Joshi and Chakravarty, 2004) productivity of animals, composition of animals, size of land holding, (Bhat and Taneja, 1998), infrastructure network i.e. A.I. facilities, trained inseminators, regular supply of quality semen etc., adoption of scientific herd management practices, marketing facilities of milk and milk products (Joshi, 2004), availability and

quality of feed, concentrate feeding and mineral supplementation (Sohi and Prasad, 2004; Joshi, 2004; Mudgal, 2004), awareness among farmers (Lal, 2000; Joshi, 2004), and management practices (Lathwal, 2004).

The studies focusing on the determinants of sustainability of crop production have carried out more systematic analysis. Bagchi and Sasmal (1995) found some agro-ecological and socio-economic parameters that have affected the sustainability of sub-humid, rain-fed, low productive rice dominated degraded mono-cropped system of a small watershed in Giridih district, Bihar. Environmental factors that are considered to a loss of sustainability are water management and different soil conditions, while the socio-economic factors include the fact that most farmers belong to small and marginal categories.

An attempt was made by Gowda and Jayaramaiah (1997) to identify the behavioural aspects of rice farmers that determined sustainability of rice farming. A sample of 200 rice growers representing canal irrigated, rainfed lowland, rainfed upland and tank irrigated rice ecosystems in India were studied for their performance on indicators of rice farming sustainability as well as 17 behavioural characteristics. Correlation, multiple linear regression and step-wise regression were used to identify the characteristics of farmers that had a significant role in managing their rice farms sustainability. Farmers representing the most sustainable system were characterized by higher family education, smaller families, larger farm size, low rice farming intensity and moderate levels of motivation and strong linkage with extension system. The pooled data analysis indicated that attitude towards sustainable farming, rice farming commitment, extension system link and innovativeness were the positive determinants of sustainable rice farming. On the other hand, economic motivation and rice farming intensity proved to be the negative determinants. The study laid emphasis on increased role for the extension system to work closely with farmers to bring about more favourable attitudes and commitment towards sustainable farming.

Bonny (1998) carried out a case study of sustainability of rice production system in Kerala. The factors which were found to affect the sustainability of the system were: production practices, community resource management, cost of cultivation, policy support and regulations, high energy consumption in farming, conservation based farming, diversification of income, training in sustainable practices, local resource dependence, preservation of paddy land conversion and knowledge of farmers in sustainable practices.

Sustainability of farming in the long run depends upon soil care and reduction in the levels of land degradation. Kumar and Padmavati (2006) characterized sustainable land management indicators and mapped them at farm level. Ecological safety, economic security and social stability explained 68 percent contribution in the sustainability of farm.

A micro-level study was undertaken by Theodore *et al.* (2001) in Tambiraparani river command area of South India, to assess and compare the economic and ecological sustainability of diversified and non diversified rice-based farming systems. They found that the sustainability of diversified farms was significantly higher than that of non-diversified farms (regardless of farm size). The economic viability of a farm was determined by the number of agricultural activities it possessed (i.e., the number of different crop and livestock) and increased with the increasing the number of activities in the system.

SUMMING UP

From reviewing the past studies it emerges that though the topic of sustainability and sustainable production has been engaging the attention of large number of researchers in our country, very few researchers have attempted to conduct systematic research on this subject in crop production and even fewer in livestock production. The studies have estimated TFP in both, livestock and crop sector, but the interpretation of the results of TFP growth from the perspective of sustainability of the production system has been done only in the studies focused on crop production.

The trend results of TFP growth in livestock and crop sector show a very interesting pattern. In the first two decades of planned economic development, the growth in livestock sector was much lower than the crop sector. The decade of seventies and eighties saw notable growth in the crop sector, while the livestock sector was gradually picking up. During the nineties when TFP growth in the crop sector languished there was a quantum surge in the same in livestock sector.

The other quantitative tools in sustainability assessment involve estimation of production and productivity growth rate and computation of composite indices covering varied dimensions of sustainability. The indexing approach has not been attempted by researchers for the Indian livestock sector, although it has been applied by a number of foreign scholars. Calker *et al.* (2004) determined various attributes for measuring sustainability of dairy farming in Netherlands, developed sustainability indices for different aspects and an overall sustainability – index using preferences of consumers, farmers, policy makers, retailers and researchers. Mann and Gazzarin (2004) analyzed the sustainability of Swiss dairy farms based on the composite index encompassing the economic, social and ecological dimensions of sustainability. The present study draws heavily from the methodological approach followed by these researchers.

Besides these methods, some other methods have been used to assess the sustainability of agriculture / livestock / dairy such as Response-Inducing Sustainability Evaluation (RISE) (Hani *et al.*, 2003) in Switzerland, Indicateurs de Durabilite des Exploitations Agricoles (IDEA) or Farm Sustainability Method (Zahm *et al.*, 2006) in France and sustainability solution space (Claudia *et al.*, 2006) in Switzerland. RISE has been successfully tested on farms with variable conditions in Switzerland, China (in collaboration with Nestle) and Brazil. However, the data requirements of these approaches is much more complex than the indexing approach.

In nutshell, the review of earlier studies brings out that empirical assessment of sustainability of livestock production and its determinants has not been attempted in systematic and comprehensive way, a gap that present study proposes to cover focusing in state of Rajasthan with the objectives enumerated earlier.

3. RESEARCH METHODOLOGY

This chapter presents in detail the data and methodology used to achieve the objectives of the study specified earlier. The chapter is divided into four sections. The first section outlines the geographical coverage of the study, section two and three describe in detail, respectively the secondary data base used and sampling technique for the collection of primary data. The fourth section presents the analytical framework for achieving different objectives of the study.

3.1 GEOGRAPHICAL COVERAGE

The study has been conducted in the state of Rajasthan at both, macro and micro level. At the macro level, total factor productivity of livestock sector is estimated for the state as a whole. Also, regional variations across various indicators of sustainability of livestock production are examined across agro-climatic zones and all 32 districts of Rajasthan. At the micro level, the study evaluates the sustainability of dairy farming in Jaipur district and analyses the determinants of sustainability. The zonal classification followed in the present study is enumerated hereinafter, while the sampling technique followed for the micro study is elaborated in the third section.

3.1.1 Agroclimatic Zone

For the present study, the boundaries of agro-climatic zones, are defined taking into consideration the zoning done by both, Indian Council of Agricultural Research (ICAR) and Planning Commission.

In 1979, ICAR launched the National Agricultural Research Project (NARP). Under NARP, the country was divided into 126 agro-climatic zones covering the major states and Union Territories of India (Ghosh, 1991). Later, few more zones were added for the remaining states / Union Territories. Presently, there are 131 agro-climatic zones in the country (Balaguru, undated).

The concept of zoning was mainly based on ecological consideration and land classification, recognizing various components like, soils, climate, topography, vegetation, crops etc. as major influencing factors. The zones were selected as contiguous areas within the state boundary and to the possible extent zones have homogenous physical characteristics. Generally, each agro-climatic zone covers 2-4 districts and may cover an area as large as 40-50 thousand sq. km. Under the NARP, one district may fall into two or more zones.

The Planning Commission (Khanna, 1989) has identified 15 resource development regions in the country, 14 in the main land and one in the islands of Bay of Bengal and the Arabian Sea. Though these 15 zones broadly present a particular agricultural situation and are indicative of agricultural potential, they did not stand the test of homogeneity when micro-variables were considered for the purpose of detailed operational planning. Keeping that in view, the 15 zones were divided into 73 sub-zones on the basis of agro-meteorological characteristics.

The sub-zoning by Planning Commission took consideration of NARP classification, although the number of sub-zones delineated by the former were of smaller number than NARP zones. Another important difference between the zoning exercise undertaken by Planning Commission and NARP is in terms of demarcation of zonal boundaries. The agro-climatic zones/sub-zones delineated by Planning Commission cut across state boundaries. On the other hand, in the NARP zones states are the indivisible units but zones tend to cut across district boundaries.

According to NARP classification Rajasthan state was divided into nine agro-climatic zones and later on one more zone was delineated. The district wise coverage under each zone is given in Appendix-I. As can be seen, few districts like, Jodhpur, Churu, Swai Madhopur, Chittorgarh and Udaipur fall in more than one NARP zone.

According to classification of Planning Commission, state of Rajasthan falls into 4 agro-climatic zones: trans Gangetic plain region, central plateau and hill region, western dry region and western plateau and hill region and

further into 9 sub-zones. The distribution of districts into sub-zones of Planning Commission indicates high correspondence with the NARP zones (Appendix-I). The agro-climatic zoning as used in the present study covering different districts is given in Table 3.1.

Table 3.1 Agro-climatic zones of Rajasthan state.

Sl. No.	Name of Zone	Districts Included
1.	Irrigated North-Western Plain	Ganganagar and Hanumangarh
2.	Semi-Arid Eastern Plain	Ajmer, Dausa, Jaipur and Tonk
3.	Flood Prone Eastern Plain	Alwar, Bharatpur, Dholpur, Karauli and Swai Madhopur
4.	Southern Plain and Aravali Hills	Bhilwara, Chittoregarh, Rajsamand and Udaipur
5.	Arid Western Plain	Barmer, Jaisalmer, Jodhpur, Bikaner and Churu
6.	Transitional Plain	Jalore, Jhunjhunu, Nagaur, Pali, Sikar and Sirohi
7.	Southern and South-Eastern Plain	Banswara, Baran, Bundi, Dungarpur, Jhalawar and Kota

The agro-climatic zone irrigated north-western plain corresponds to zone IB of NARP, semi-arid eastern plain to IIIA, flood prone eastern plain to IIIB and southern plain and Aravali hills corresponds to zone IVA of NARP. The agro-climatic zone arid western plain includes districts of zone IA and Zone IC, transitional plain comprises districts of zone IIA and Zone IIB and south eastern plain consists of districts of zone IVB and V of NARP.

In keeping with the approach followed by planning commission, district was taken as the smallest unit and the agro-climatic zone demarcated in the present study did not cut across district boundaries. This was particularly important, as secondary data used in the study was available at district level.

3.2 THE DATABASE

The study is based on both, primary and secondary data. The details about sources and nature of data used are elaborated below:

3.2.1 Secondary Data : Source and Description of Variables

The secondary data on a large number of variables such as value of output from livestock sector, value of inputs used for livestock production, livestock population, production of livestock products like, milk, meat, egg, wool, etc., output as well as input prices, land utilization, cultivators and agricultural labourers, etc.; at the state or district level, as per the requirement, were either collected or estimated using information from various published and unpublished sources. Detail description of the variable and their data sources is as follows:

STATE LEVEL

3.2.1.1 Value of output

The state level data at current and constant prices (base 1993-94) on value of output from livestock sector, disaggregated by 7 groups viz., milk group, meat group, eggs, wool and hair, silk worm cocoon and honey, dung and increment in stock were collected from Central Statistical Organization (CSO, 2006) for the period 1990-91 to 2004-05. For the earlier years of study viz. 1960-61 to 1989-90, it was estimated based on methodology suggested by CSO.

Evaluation of value of livestock production is done by multiplying the quantities of production by the corresponding wholesale prices. The specific data sources used in this exercise are as under:

Production :

Milk group: The milk group comprises milk consumed or sold in fluid form, ghee, butter and lassi produced by the producer households. As per the observation made by CSO (CSO, 2004), the quantity of milk used for conversion into ghee, butter and lassi by the producer households was quite minimal and the products converted are consumed mostly by the households themselves. Moreover, reliable price statistics are not available in respects to these products. Thus the evaluation of milk has been done as though it is consumed and sold in the fluid form itself. The data on milk production was collected from State Animal Husbandry Department.

Meat group: Meat group comprises meat (beef, mutton, pork including edible offal and glands and poultry meat), meat products (fat, heads, legs) and by-products comprise hides (cattle and buffaloes hides), skins (goat and sheep skin) and other products (guts, blood, bones, horns, hoofs, tail stumps, useless meat and esophagus).

The annual meat production figures (excluding poultry meat) for the period 1985 onwards was directly collected from the reports of Integrated Sample Survey for Estimation of Major Livestock Products (ISS) of State Animal Husbandry Department. For the previous years, estimation was based on livestock population, number of animal slaughtered and meat yield. The data on different species of livestock population was collected from Livestock Census Reports and for non-censal years, it was estimated based on intercensal growth in livestock population of respective category. The slaughtering percentage for buffalo, goat and sheep and average meat yield was used from a survey report for estimation of meat production in Rajasthan (Madan and Purohit, 1966) while, for pork production these estimates were collected from the report of Directorate of Marketing and Inspection (DMI, 1969) (see Appendix-II). Then the number of animals slaughtered were multiplied by average meat yield to get the annual meat production from different species.

The estimates of poultry meat were prepared using the information on utilization of eggs and chicken survived. These data were collected from poultry survey related to Rajasthan (IASRI, 1966). Poultry meat was estimated in terms of number of adult fowls and chickens slaughtered. Poultry meat production equals 50 percent of the adult fowls plus chickens and duckling killed. The latter is worked out as estimated number of chickens during the year plus chickens survived during the year plus 50 percent of adult fowls minus estimated number of total fowls of the following year.

The estimates of other meat products and by-products are based on the number of slaughtered animals and fallen animals wherever applicable and the corresponding yield rates. The basic data relating to yield rates edible offals, fat and other byproducts (guts, oesophagus, tail stumps, useless meat

and blood) were taken from a report on animal by-products (DMI, 1961). The yield rates for bones, horns and hoofs per animal were taken from relevant DMI reports for 1957 and 1961. The by-product estimates were worked out for each category of animals by applying the state average yield rate on the estimated annual number of slaughtered animals. Hides and skins are obtained from (a) animals slaughtered for production of meat and (b) animals fallen due to natural death. Estimates of the number of animals fallen as given in the relevant marketing report (DMI, 1961) are projected to later years on the basis of the movements in the estimated population of animals.

Eggs: The ISS reports provided the data on egg production after 1985. For the period 1960-61 to 1984-85 it was estimated based on number of layers and average egg production per layer. The number of layers and average egg production per layer was collected from State Department of Animal Husbandry.

Wool and hair: Once again, the wool production from mid 80 onwards was taken from ISS reports and for the earlier years it was worked out as product of sheep population, proportion of sheep sheared and average fleece weight. The average fleece weight, the percentage of sheep clipped for wool and the number of clippings per sheep per year were collected from DMI report on wool marketing (DMI, 1957), while the sheep population was based on Livestock Census. Sheep population for non-census year was based on the inter-census growth in the sheep population.

The estimates of goat hair and pig bristles were prepared on the basis of information on yield per animal. In case of goat, average yield rate was used as given in the relevant marketing report of DMI (DMI, 1961). Average yield rates of pig bristles were estimated as 155 g per pig per year (CSO, 2007). As regards camel hair, the average yield rate of camel hair as 700 g/animal/year was used (Mehta *et al.*, 2007). The benchmark estimates of hair and bristles are carried forward/backward using relevant category of population.

Silkworm cocoon and honey: As the production of silkworm cocoons and honey is negligible in Rajasthan, the value of output of these products was obtained from all-India figures (for 1960-61 to 1989-90). The average share of Rajasthan in all-India value of production during 1990-91 to 2004-05 was calculated and was applied for previous years.

Dung: The estimates of production of dung are prepared on the basis of average body weight, dry matter intake and digestibility percentage. The average body weight, dry matter intake were collected from Singhal *et al.*, 2002 (see Appendix-III), while the digestibility percentage were taken as 50 percent for cattle and buffalo, 60 percent for camel, horse and ponies, mules and donkeys, 70 per cent for pig and 80 percent for sheep, goat and poultry (Maynard *et al.*, 1981).

Draft Power: The CSO estimates do not provide value of output from draft power. Hence, the data series on animal draft power was generated on the basis of some realistic assumptions as used earlier in the literature (Pandey *et al.* 1983 Kumar and Pandey, 1999; Elumalai and Pandey, 2004). These assumptions are:

- (a) Horsepower availability from per animal of bullocks, he-buffalo, horse and ponies, mules and donkey of above three years was assumed 0.5 HP while those of camels above four years each 1 HP.
- (b) The working days per animal was assumed at 100 days in a year.

The quantum of draft power was converted into fuel equivalent required by a tractor to do same amount of work. Average price of diesel was multiplied to get the value of output of draft power.

Increment in stock: The annual net increase in the livestock population was estimated for each category of livestock on the basis of Livestock Census results. The population for the inter-census years was projected on the basis

of inter-census growth rate. The resulting annual incremental livestock population was converted into Adult Cattle Unit (ACU)¹ and was multiplied by prices of adult cattle to get value of increment in stock.

Prices :

The wholesale prices were used along with the production estimates as mentioned above for obtaining the value of output. The wholesale prices of milk, meat and some meat by products (hides and skin), egg, wool, diesel, and livestock prices were taken from Agricultural Prices in India or State DES. Prices of meat product (fat, heads, legs) and other meat products (guts, blood, bones, horns, hoofs, tail stumps, useless meat and esophagus) were collected from DMI for some initial years while for later period these were estimated by moving the wholesale price index of relevant group. The time series prices of dung were not available for the state, therefore prices of dung from neighbouring state of Haryana were used which were collected from various issues of Farm Management Extension Bulletines of CCS, Haryana Agricultural University, Hisar.

3.2.1.2 Value of Input

Unlike the value of output, CSO did not provide the data on value of livestock inputs at state level for any of study years. The input value was therefore, estimated based on relevant assumptions. To estimate the value of input, three inputs were considered namely, feed, labour and interest on value of stock. The detailed description of the data adjustments and assumptions are given below.

¹ The conversion coefficient are used as proposed by Kumbhare *et al.*, (1983) and Bhati (1981) as given below:

Local cow	= 1.00	Crossbred heifer >1 yrs.	= 0.75
Crossbred cow	= 1.40	Calf of Buffalo and local cow > 1 yr.	= 0.50
Buffalo	= 1.30	All calves < 1 yr.	= 0.33
Bullock/he-buffalo	= 1.00	Goat and Sheep	= 0.50
Local cow /Buffalo heifer >2 yrs	= 0.75	Other animals	= 1.00

Production:

Feed : Livestock feed comprises (i) roughages which include straw and stalk, fodder (green and dry), grass, etc. and (ii) concentrates which are made up of oilcakes, crushed pulses, grains, wheat and rice bran, husk, etc.

For roughages, 95 percent of production of stalks and straws, the entire production of fodder, cane trash and grass in the agriculture sector are considered to be consumed by livestock. Therefore, the value of dry fodder taken as 95 percent of value of straw and stalk produced in Rajasthan as reported by National Account Statistics.

To estimate the fodder production, the data on area under fodder crops, both irrigated as well as unirrigated, area under pasture and grazing lands, area under forest were collected from Land Utilization Statistics published by the Directorate of Economics and Statistics, Government of India. The average yield per hectare of 1.5 tons from the forest areas, 0.75 ton from permanent pasture and grazing lands, and 40 and 20 tons from irrigated and unirrigated areas, respectively, were used to estimate the fodder production (DAHD, Undated).

The concentrates are made up of oilcakes, crushed pulses, grains, rice and wheat bran. It was assumed that 2 percent of wheat, 10 percent of maize, 1 percent of rice, 5 percent of barley, sorghum, pearl millet and finger millet are fed to the animals (Jain *et al.*, 1996). The value of these concentrates was estimated by applying the corresponding percentage to the value these grains. The value of grains was collected from CSO. In addition to the grains, wheat bran and rice polish have been estimated to be 6 percent of wheat production and that of rice polish to be 3 percent of rice production, respectively (Jain *et al.*, 1996). The major oilseed crops grown in the state are rapeseed and mustard, groundnut, sunflower, soyabean, linseed, sesam, nigerseed, and cottonseed. To estimate the production of oilseed cakes, the ratio of meal to seed was used as 55.7 percent of rapeseed and mustard, 31.7 percent of sunflower, 29.5 percent of soyabean, 44.9 percent of

groundnut, 67 percent of linseed, 39.4 percent of seasmum and nigerseed, and 10.4 percent of cottonseed (per bale) (Ranjhan *et al.*, 1999). The data on oilseed production was collected from State Department of Agriculture.

Labour : To workout the value of labour force engaged in livestock sector, the data of cultivators and agricultural labourers were collected from population census. Data in between the census was projected on the basis of the growth of the population of cultivators and agricultural labourers. Therefore, after 1/4th male and 3/4th female in each category was considered to be employed for livestock rearing and maintenance. Further, it was assumed that three women were equivalent to two men (Elumalai and Pandey, 2004).

Interest on population stock : Interest of 9 percent was charged on the value of livestock population. To workout the value of livestock population, all species of livestock were converted into Adult Cattle Unit (ACU). and multiplied by prices of adult cattle.

Prices :

The prices of animals, oilcakes, fodder, grasses and wheat and rice bran were collected from Agricultural Prices in India and State Directorate of Economics and Statistics, while, the wage rates were collected from various issues of Agricultural Wages in India.

DISTRICT LEVEL

District level data pertaining to latest three years from 2003-04 to 2005-06, for a large number of variables were collected to carry out the second objective of the study. These data were also used to build the database at the level of agro-climatic zones.

District Statistical Outlines were the data source for output and input prices, while recent livestock production figures were obtained from ISS. The labour statistics and literacy rates at district level were available in Population Census. Information on livestock population was collected from livestock census, whereas data on number of livestock institutions were collected from

State Department of Animal Husbandry, Jaipur. Land utilization (net sown area, area under forest, permanent pasture and grazing land, orchards etc.) was taken from Agricultural Statistics in India. Production of various cereal crops, oilseeds, green fodder crops, etc. was obtained from various District Statistical Outlines published by Directorate of Economics and Statistics, Jaipur.

3.2.2 Primary Data

The primary data were collected for the year 2006-07 (March 2006 to February 2007) by conventional survey method on a well structured and pre-tested schedule through personal interview from 120 selected households for three seasons, viz., summer (March to June), rainy (July to October) and winter (November to February). The information was collected on socio-economic characteristics of the households such as family education status, size of holding, communication characteristics, farm building, machinery, equipment and various other aspects of enterprise like, inventories relating to dairying, size and composition of herd, value of milch animals, milk production and consumption, feed inputs, breeding practices, veterinary and miscellaneous expenses incurred, hired and family labour employed in dairy operations, and prevailing wage rates, manually weight loaded per person, prevailing prices of milk, prices of inputs and outputs, quantity of dung produced, utilized, etc. Besides these data from sample households, general information like veterinary infrastructural facilities available were also collected from selected villages. Sampling technique for the selection of households is enumerated in the ensuing section.

3.3 SAMPLING TECHNIQUE

Jaipur district was purposively selected for studying the sustainability of dairy farm at household level. The district is the best in the state in terms of dairy production. It is the highest milk-producing district accounting for around 8.05 per cent of the total milk production of the state. Jaipur also has the highest population and productivity of dominant milk producing species in the

state, namely the buffaloes. The district was, therefore, considered as the best case in the state to study sustainability of dairy farming and hence, selected purposively².

3.3.1 Selection of Tehsils and Villages

Out of 13 tehsils of Jaipur district, four tehsils, Chomu, Jamwaramgarh, Bassi and Phulera were selected randomly. One village from each tehsil, namely, Raisingh Ka Bass from Chomu, Jaichandpura from Jamwaramgarh, Dudhawala from Bassi and Nathi Ka Bass from Phulera were selected randomly.

3.3.2 Selection of sample households:

A complete enumeration of selected villages was carried out to identify the major farming systems and ascertain the herd size of milch animals in the study area. In all, there were 536 households in 4 sample villages, out of which, 471 owned dairy animals. The various farming systems that emerged from the exercise, in the descending order of percentage among households practising dairy husbandry, were: (i) Crop + dairy, (ii) crop + dairy + ovine, (iii) crop + dairy + ovine + cameline, (iv) dairy, (v) dairy + ovine, and (vi) dairy + cameline. The number of households were very less in last four systems. Therefore, these systems were grouped under others category.

Three-herd size categories based on number of milch animals (both, cows and buffaloes) were formed using cumulative square root frequency method. These categories were: small (1-2 animals), medium (3-4 animals) and large (5 and above animals). The dairy farmers were cross-categorized according to farming systems and herd size category. The total number of 120 households was selected as per the probability proportion to number of households in each category. Thus, the sampling of respondents was representative of major farming systems and herd size categories. The numerical figures pertaining to cross categorization are given in Appendix-IV.

² Ideally, one best and one worst district would have been more representative but due to paucity of time and resources at the disposal of lone researcher, and already large quantum of work proposed in the present study, only the best case was taken.

3.4 ANALYTICAL FRAMEWORK

This section presents the tools and techniques used to achieve different objectives of the study. Objective wise detail is given as under:

3.4.1 Estimation of Total Factor Productivity

The review of literature brought out that growth trends in Total Factor Productivity (TFP) indices have been used for assessing the sustainability of agricultural production system. Total factor productivity is defined as increase in total output, which is not accounted for by increase in total inputs. The total factor productivity index is computed as the ratio of an index of aggregate output to an index of aggregate inputs. Growth in TFP is, therefore, the growth rate in total output less the growth rate in total inputs.

Total factor productivity in the present analysis has been calculated by using Tornqvist-Theil index, a discreet version of the continuous Divisia-Tornqvist index, which is used for application in data at discreet point of time. The Tornqvist-Theil index provides consistent aggregation of inputs and outputs under the assumptions of competitive behavior, constant returns to scale, Hicks-neutral technical change, and input-output separability. Diewert (1976) has shown that this is a superlative index, which is exact for the linear homogeneous translog production function. However, Caves *et al.* (1982) have shown that Tornqvist-Theil indices are also superlative under very general production structures, i.e., nonhomogeneous and nonconstant returns to scale, so they should provide consistent aggregation across a range of production structures (Antle and Capalbo, 1988).

A further advantage of the Tornqvist-Theil index is that it accounts for changes in quality of inputs, because current factor prices are used in constructing the weights. The quality improvements in inputs are incorporated, to the extent that these are reflected in higher input prices (Capalbo and Vo, 1988). In the present analysis, however, the index has been computed at both, current and constant output and input prices, taking 1993-94 as the base year.

The general formula used for construction of index is as follows :

$$\text{Total output index (TOI)} = \text{TOI}_t / \text{TOI}_{t-1} = \Pi_j (Q_{jt} / Q_{jt-1}) (R_{jt} + R_{jt-1})^{1/2}$$

$$\text{Total input index (TII)} = \text{TII}_t / \text{TII}_{t-1} = \Pi_i (X_{it} / X_{it-1}) (S_{it} + S_{it-1})^{1/2}$$

Total factor productivity index (TFPI)

$$\text{TFPI}_t = (\text{TOI}_t / \text{TII}_t) \times 100$$

Where,

R_{jt} = Share of output 'j' in total revenue from livestock products in tth time period,

Q_{jt} = Output of jth livestock product, (j= milk group, meat group, eggs, wool and hairs, silkworm cocoon and honey, increment in stock, dung and animal draft power)

S_{it} = Share of input 'i' in total input cost,

X_{it} = Quantity of ith input in period 't'. (i = animal feed and fodder, labour and interest on population stock)

By specifying TOI_{t-1} and TII_{t-1} equal to 100 in the initial years, the above equations provide the total output, total input and total factor productivity indices for the specified period 1960-61 (t=0) to 2004-05 (t=T). The indices are presented with base 1960-61 =100.

The growth rate of TFP has been computed at current as well as constant prices (1993-94 prices). To arrive at the value of output and input at constant prices, value of these products at current prices was deflated by Wholesale Price Index (WPI).

After construction of the output, input and TFP indices, the growth rates of these indices were computed using the compound interest formula as given below :

$$Y = ab^t$$

Where,

Y = Total output / input / TFP indices,

t = Time in years,

b = Compounding factor and $b = (r+1)$.

Where,

r = Compound growth rate per unit of output / input / TFP index per annum

Thus,

$$Y = a(r+1)^t$$

On making log transformation of this equation :

$$\text{Log } Y = \text{Log } a + t \log (1+r)$$

$$\text{Or } \text{Log } Y = \text{Log } a + t \log b$$

$$\text{Compound growth rate "r" = } [(Antilog \text{ of } \log b) - 1] \times 100$$

The output covered milk group, meat and meat products, egg, wool and hair, dung, increment in stock, animal draft power and some other miscellaneous products like silkworm cocoons and honey. To estimate the input value, feed, labour and interest on value of stock was considered.

3.4.2 Sustainable Livestock Production Index (SLPI)

The multi-dimensional concept of sustainability of livestock is considered to be composite of three indices, i.e., Economic Efficiency Index (EEI), Social Equity Index (SEI) and Ecological Security Index (ESI) so that it can take stock of both, the conflicts and synergy between ecological, economic and equity aspects of sustainable development of livestock. The dynamic and contextual nature of sustainable development of livestock renders sustainability need to be relative rather than absolute both, in time

and space, i.e., the sustainability potential of any region should be constructed with that of other region or against some established norms or conventions. Therefore, taking the cue from Saleth (1993), Sustainable Livestock Production Index (SLPI) was constructed by compositing three indices, viz., EEI, SEI and ESI. In each of the components of sustainability, various indicators were used. The *a priori* reasoning for the choice of the indicators and its components is detailed below.

ECONOMIC EFFICIENCY INDEX (EEI)

Economic sustainability implies maintaining or improving production without reducing the stock of natural capital and production capacity. It is reflected by three variables, viz., livestock productivity, labour productivity and per capita calories availability from livestock products.

Livestock productivity: Expressing productivity in monetary units helps not only physical productivity as influenced by feed and fodder quality, climate and technology, but also the performance of marketing and other rural institutions affecting the farm prices. Higher livestock productivity leads to higher profitability of livestock and ultimately has positive impact on sustainability of livestock production. The livestock productivity was captured as the value of various items of livestock products in rupees per livestock unit, i.e.,

$$\text{Livestock productivity (Rs.)} = \frac{\text{Value of various items of livestock products (Milk, meat, wool and eggs)}}{\text{Livestock units (in SAUs)}}$$

Livestock units is the number of standard animal units in the district / zone and used as proposed by CSO, discussed earlier.

Labour productivity: Labour productivity reflects the efficiency of labour in livestock sector. There is direct relationship between labour productivity and sustainability of the system. The labor productivity was measured as given below:

$$\text{Labour productivity (Rs.)} = \frac{\text{Value of various items of livestock products}}{\text{Labour employed in livestock sector}}$$

For labour employed in livestock sector, the assumptions were used as discussed in previous section.

Per capita calories availability from livestock products: Value of livestock products is an important variable, however, it has the potential to bias the region specialized in high value products. It is to counter such a bias; the variable per capita energy availability from livestock products was included for economic sustainability. This also has potential to say something about the food security aspect for the district / zone. It was captured as per capita availability of different edible animal products (milk, meat and eggs) multiplied by energy content in respective product. The energy content in each product was taken from publication by Narasingh *et al.* (1991).

SOCIAL EQUITY INDEX (SEI)

For sustainability of a system, it should be socially equitable. The social requirements for livestock farming are many, but female literacy, access to public infrastructure facilities for livestock and growth rate of Common Property Resources (CPRs) are taken as the most important ones for the sustainability of livestock production system from the social perspective.

Female literacy rate: Females have predominant role to play in livestock production systems and account for 69 per cent of the total work force in the livestock sector. Therefore, female literacy captures social equity, indicates the potential not only for women's social and economic participation but also for population stabilization. It has positive relation with sustainability.

Access to public infrastructure facilities for livestock: The livestock support services have vital role to play in enhancing the productive performance and hence, sustainability of livestock production system. In the scenario where such facilities are largely provided by the state, their access and quality has important bearing on the sustainability. In absence of quantifiable data for capturing quality aspect, the study takes into account the inter district variations in access to public infrastructure as an indicator, with the presumption that higher density of such facilities imply a better access to the

public thus, contributing positively to social dimension of sustainability. Hence, this variable is captured through number of veterinary health, breeding and extension institutions per square km of geographical area of district / zone. Health institutions included number of hospitals, dispensaries, sub-centres, diagnostic units, etc. while breeding institutions included AI centres and sheep breeding farms. Sheep breeding extension centres, training institutions were included as extension institutes.

Growth rate of CPRs: Rural inequalities generated by Private Property Resources (PPRs) based farming system are partly reduced by CPRs as the resource poor households significantly supplement their income from CPRs. It also contributes to poor man's nutrition by facilitating his food gathered from forests, pastures and grazing lands. A negative or low positive growth rate has adverse implications for sustainability of livestock production system.

ECOLOGICAL SECURITY INDEX (SEI)

Ecological security is reflected by two variables, viz., proportion of area under pasture and grazing land to net sown area and percentage of surplus animals in relation to feed and fodder availability.

Proportion of area under pasture and grazing land to net sown area: Pasture and grazing lands are the most valuable habitats for maintaining the wide flora and fauna in the agricultural landscape. Sufficient area under pastures and grazing land is normally the most appropriate way to preserve the quality of land. Higher the area under pasture and grazing land has positive impact on sustainability of the system.

Percentage of surplus animals in relation to feed and fodder: This variable captures the carrying capacity of land. Increase in animal numbers triggers a vicious circle of continuous livestock increase, soil deterioration and land degradation encroachment of fragile high land environment. The preceding circle causes sharp acceleration of environmental degradation consequent to surpassing carrying capacity and sustainability of natural environment.

While examining the question of surplus livestock population, the first step is to find out the 'normal' carrying capacity or the 'equilibrium' livestock population of the region that the ecosystem and fodder supply can sustain. This necessitates to estimate the available amount of fodder (on dry matter basis) from different sources in each district / zone and the normal consumption capacity of the animals. The sources of dry matter are grass and hay obtained from the pastures, grazing lands, forests, fodder crops, crop dry-products and grass from orchards and concentrates from grains, wheat and rice bran, and cakes. The capacity of consumption for the appetite of the animal is measured by the amount of dry matter in the ration, which an animal can consume. The dry matter consumption was used @ 7 kg/ACU/day³ (i.e. 2% of the body weight of 350 kg). This amounts to 2555 kg (2.555 tons) dry matter per year per cow. By dividing the availability by the recommended nutritional requirement of one standard animal unit the maximum number of animals that can be sustained on the total feed availability in the district / zone was worked out. The difference between the actual livestock population and the optimum sustainable population is the surplus population of livestock in standard animal units was obtained.

Despite their limitations, the selected variables do have a good capacity to reflect the overall economic, social and ecological aspects of a region's livestock production system. Two observations are due in this regard. First, the variable actually selected to represent a given dimension also reflected the concerns in the other dimensions of livestock sustainability. And, second most of the variables display both positive and negative correlations among them, which rather than being a problem, actually enhance the capacity of SLPI to capture both, the inherent conflicts as also the intrinsic synergy among various aspects of livestock sustainability.

³ Report of the Working Group on Animal Husbandry and Dairying for the Tenth Five Year Plan (2002-2007) Government of India, Planning Commission, January - 2002 Working Group Sr. No. 42 /2001

Construction of SLPI

The SLPI is the generalization of relative approach underlying the Human Development Index developed by UNDP (1990). The steps for developing this index are as follow:

The *first step* is to construct the index (I_{ijk}) for each i^{th} indicator/variable representing j^{th} component of SLPI of k^{th} region. The equation for the indicators having positive effect on sustainability viz., livestock productivity, labour productivity, per capita calories availability from livestock products, female literacy, access to public infrastructure facilities for livestock, growth rate of CPRs, and proportion of area under pasture and growing land to net sown area is used as

$$I_{ijk} = \frac{X_{ijk} - \text{Min} X_{ijk}}{\text{Max} X_{ijk} - \text{Min} X_{ijk}}$$

Where, X_{ijk} represents the values of i^{th} variable representing j^{th} component of SLPI of k^{th} region.

$$i = \text{No. of indicators} \begin{cases} = 3 \text{ for EEI} \\ = 3 \text{ for SEI and} \\ = 2 \text{ for ESI} \end{cases}$$

$$j = EEI, SEI \& ESI$$

$$k = 1, 2, \dots, 32 \text{ (for district level index) and } 1, 2, \dots, 7 \text{ (for agro-climatic zones level index)}$$

While, the equation used for the indicator, percentage of surplus animals in relation to feed and fodder availability is as given below (as higher the value of indicator less will be the sustainability):

$$I_{ijk} = \frac{\text{Max} X_{ijk} - X_{ijk}}{\text{Max} X_{ijk} - \text{Min} X_{ijk}}$$

The numerator in equation (1) measures the extent by which the k^{th} region is better in the i^{th} variable representing j^{th} component of its SLPI as compared to the region(s) sharing the worst performance. The denominator is actually the range, i.e., the difference between the maximum and minimum value of given variable across the regions, which is simple statistical measure of total variation presented in the variable.

Having calculated the I_{ik} for all the variables, the *second step* is to calculate the indices for various components of SLPI. It is calculated as the simple mean of the indices of their respective variables, that is :

$$EEI_k = \frac{\sum_{i=1}^3 I_{ik}}{3}, \quad SEI_k = \frac{\sum_{i=1}^3 I_{ik}}{3}, \quad \text{and} \quad ESI_k = \frac{\sum_{i=1}^2 I_{ik}}{2}$$

Then, the composite index for each region was calculated as a weighted mean of the indices obtained from equation, i.e.,

$$SLPI_k = \frac{W_1 * EEI_k + W_2 * SEI_k + W_3 * ESI_k}{3}$$

Where 'W' denotes the weight assigned to the respective component of the SLPI of k^{th} region and has the property that:

$$W_1 + \dots + W_3 = 1$$

Two weighting schemes were used :

(1) Taking equal weights, that is, $W_1 = W_2 = W_3$. The index so developed was denoted simple SLPI and

(2) Different weight: Under this approach, first, the inverse of the proportional contribution of EEI, SEI and ESI to the SLPI was obtained. And then, the weight assigned to each component was the ratio of this inverse contribution to the sum of all the three inverse proportions. Despite its heuristic nature, it has the following appeals: (i) the relative significance of the components of SLPI varies by regions and (ii) the weights assigned are also inverse to the relative significance of the three components as reflected by their values.

3.4.3 Sustainable Dairy Farming Index (SDFI)

The methodology developed by Mann and Gazzarin, (2004) for assessing the sustainability of Swiss dairy farms was adapted and modified to be used in Indian context. The sustainability of dairy farming at farm level was evaluated through construction of Sustainable Dairy Farming Index (SDFI) for each of 120 sample households. As in case of SLPI at district level, the SDFI at household level used all the three dimensions of sustainability. The indicators used at the farm level however, are not same at the regional level. The steps for developing this index are as follows :

Step-I : Indicators :

The *first step* in construction of the index is identification of dimensions/aspects of sustainability. The review of literature had explicitly brought out that sustainable dairy farming was based on economic, environmental and social dimensions. Hence all three dimensions were taken into account.

The indicators for each dimension and method of assigning the scores to each component / indicator is as given below.

(A) Economic Indicators

Dairy farms are business units that produce just homogenous product with a limited range of cost factors making the definition of economic indicators for economic sustainability straightforward. At the same time, the use of 'classical' economic business is limited, as the accounting system of farms differs considerably from that of other enterprises. The study considers economic dimension of sustainability to be based on two important pillars viz., production cost and input productivity.

Table 3.2 Economic indicators of sustainability and corresponding variables.

Sl. No.	Indicators	Variables
1.	Cost of Milk production (Rs./litre)	<ul style="list-style-type: none">• Total cost (Rs.) (consist of cash costs, depreciation, interest on fixed capital and opportunity cost of owned farm factors of production such as family labour, owned land, owned capital in the form of fixed assets and equipments).• Value of Dung (Rs.)• Milk yield of cow (crossbred and local) and buffalo (litres)
2.	Labour productivity (Rs./manday)	<ul style="list-style-type: none">• Milk output (Rs.) = Milk production (lit.) x Price of milk (Rs.)• Man days of labour in dairying
3.	Capital Productivity (Rs.)	<ul style="list-style-type: none">• Net annual income = Gross income - Gross cost• Average value of total dairy assets (Rs.)
4.	Feed productivity (litre/kg dry matter intake)	<ul style="list-style-type: none">• Milk produced (lit.)• Dry matter intake (Kg.)

(a) *Cost of milk production*: Production cost reflects the profitability of dairy enterprise and ultimately the sustainability of the farm. Higher cost makes the enterprise less profitable. Therefore, higher cost has negative effect on sustainability of dairy farming. It is captured in rupees per litre of milk produced and is worked out as under :

$$\text{Cost of milk production} = \frac{\text{Total cost} - \text{Value of dung}}{\text{Milk yield}}$$

(b) *Input productivity*: reflects the efficiency of inputs used for producing milk. Higher the productivity of inputs means the more efficient use of inputs and therefore, more will be the sustainability of the farm. Productivity of three major dairy inputs, viz. labour, capital and feed was captured as given below:

(i) *Labour productivity*: has positive relation with sustainability of dairy farming. It was measured in terms of value of milk produced per manday, i.e.,

$$\text{Average productivity of labour} = \frac{\text{Milk output (Rs.)}}{\text{Man days of labour in dairying}}$$

(ii) *Capital Productivity*: Capital productivity has positive effect on sustainability. It was measured in terms of Rate of Return on Assets employed in dairy sector, i.e,

$$\text{Capital productivity} = \frac{\text{Net annual income (Rs)}}{\text{Average total dairy assets}}$$

(iii) *Productivity of feed input*: Productivity of feed input was measured by milk produced (in litres) per kg. of dry matter intake i.e,

$$\text{Feed Productivity} = \frac{\text{Milk produced (litres)}}{\text{Dry matter intake (kg)}}$$

(B) Social Indicators

Basic social requirements of sustainable dairy farm are that family as a group earns sufficient income, that there should be no gender discrimination or gender bias and that workers work under the conditions that do not put

their health at risk. Therefore, this dimension of sustainability was reflected in three variables viz., family labour income, women empowerment and drudgery of work.

(a) Family Labour Income from Dairy as Percentage of Total Monthly Per Capita Consumption Expenditure (MPCE)

Family labour income (FLI) is an indicator of social dimension of sustainability because sufficient family labour income is one of the main reasons that farmer's family continues to work in dairy activities and fulfill its obligations of residing in the rural areas and producing milk for urban consumers. The sufficiency of family labour income was evaluated in relation to the average MPCE of rural households in Rajasthan with the idea to see that how much of per capita family labour income is earned from dairy enterprise in relation to MPCE. The higher this proportion the greater would be positive effect on sustainability. Per capita family labour income was worked out as follows:

$$FLI = \left[\text{Gross income} - (\text{Cost of feed, fodder, concentrates, other paid cost and depreciation} + \text{Interest on fixed output}) \right] / \text{Family size}$$

The information on average rural per capita MPCE for Rajasthan state was taken from NSSO (2006).

(b) Women empowerment

Empowerment of women is one of the most important indicators of social dimension of sustainability. It is important to take into account some aspects of female empowerment like, economic participation, political participation and power over economic resources.

To measure the degree of empowerment, the present study used Weighted Average Method in order to calculate the empowerment index by using 5 proxy variables. The index was framed by reviewing many of earlier literature like Gender Empowerment index of UNDP's Human Development Report (1995), Kabeer (1999), Malhotra *et al.* (2002) and Sridevi (2005). The important variables deciding the empowerment of rural women were taken as:

(1) Access to or control over financial resources, (2) Participation in domestic decision-making, (3) Educational qualification and, (4) Social participation and (5) Accessibility to information.

These proxy variables were framed in the form of scale, such as on domestic decision-making scores is: 0 = if the respondent is not consulted, 1= if she is consulted, 2= if respondents decide together, 3= if the respondent consults others and decides herself and 4= if she decides herself. Detailed questionnaire used for the purpose is given in Appendix-V. The obtained raw scores were converted into standard scores⁴ by converting the scale.

Finally the empowerment index was calculated for each household, using these proxies. Equal weights were given to all the 5 components for constructing the empowerment index.

(c) Drudgery of work

The farmer should work under the conditions that have minimal drudgery and help them work more efficiently. Traditionally, the condition under which labour (particularly physical labour) takes part is an important indicator of social situation of the respective sector. It was captured in three components viz., sharing of burden among the number of persons in each activity, carrying of weight/load and days off work affordable by main worker.

⁴ The standard score was converted by converting raw scores into z score and then X' scores. The formula used to transform raw scores into z scores entails subtracting the mean from the raw score and dividing by the standard deviation.

$$Z = \frac{X - M}{SD}$$

While z scores are relatively simple to use, they do have some computational disadvantages. Because a z score can be equal to 0 or can be negative, certain types of data manipulation become awkward. For these reasons, as well as others, alternative standard score systems have been developed to linearly transform z scores (as well as raw scores) to a scale that does not contain negative numbers. Such systems are all "standardized" to the extent that both the mean and the standard deviation of the new scale have been arbitrarily set. The general formula for linearly converting a z score to a standardized score (X') is expressed as follows:

$$X' = SD(z) + M$$

Where:

X' (called X prime) is the new standard score, and M and SD are the values of the mean and standard deviation, respectively, of the new distribution.

(i) *Sharing of burden among the number of persons in each activity involving physical labor:* Dairy activities involving physical work were grouped into three categories viz., cleaning, feeding and milking. Scores were given to each activity based on sharing of burden of that activity among the number of persons e.g. 0=if one person bears the burden, 1=if two persons share the burden and so on. Then the raw scores were converted into standard scores. Finally, weighted index was calculated from these standard scores for each household. Weights were assigned on the basis of main worker's perception for ranking of activities according to the level of drudgery.

(ii) *Carrying of weight/load:* This part of the social indicator gives base to judge the labour condition in dairying. Often manual work like frequent carrying of heavy weight may act as disincentive for continuing dairy in the longer run, particularly for the educated youth. Therefore, this variable is captured as product of weight (in Kgs.) carried manually by a worker, distance through which weight has to be carried and frequency of activity.

(iii) *Days off work:* Another issue that is largely unsolved for dairy farming is the availability of spare time. Dairy farming is largely done by women and the work sharing is either negligible or shared by few persons. They engage throughout the years in dairy activities and can seldom afford to leave the farm household as they have to tend their dairy animals. It has been observed that due to the regular nature of this activity whereby the work has to be carried out daily, the farm households consider it to be a drudgerious task. Thus, the number of days that the main worker can afford to take off from the dairy activity was taken as an indicator whereby higher number of days affordable to be taken off implied lesser drudgery.

(C) Ecological Dimension

The interaction between dairy farming and the environment are manifold. The goal of a sustainability index is to include the most significant environmental impacts of dairy farming and the once with the greatest variations between dairy farms. Therefore, environmental factors were reflected by three variables viz., use of dung, enteric methane emission and breeding practices.

(a) Use of dung

In Rajasthan, as in other parts of India dung is extremely used for two main purposes: fuel and manure. Cooking with dung cakes is not only difficult and inefficient but also health hazardous and air polluting. However, when dung is used as manure and applied to crop, it improves soil texture, checks soil salinity and alkalinity and soil erosion. Thus, from environment point the use of dung for manures is favorable for sustainability. Therefore, the ratio of dung used as fuel to manure is taken as an indicator of ecological dimension; the higher the ratio, the lower is the sustainability.

(b) Enteric methane emissions

Methane production from animal system has assumed significance from the environmental perspective due to its role as a green house gas. The lower level of methane emission in relation to milk produced by dairy animals is desired for both, production efficiency of animals and ecological sustainability. As enteric fermentation is the major source of methane production in dairy animals, this indicator of ecological sustainability was captured as enteric methane emission per kg of milk produced. To calculate the methane emission per litre of milk produced by a household, three variables are required : species-wise methane emission factors for dairy animals, number of dairy animals of different species and their milk production. The information on later two variables was collected through direct interview / observation as mentioned earlier. While for methane emission factor, the region specific emission factors were generated to ensure accuracy. The emission factors for the study area was generated using the Tire-II approach proposed by Inter-governmental Panel on Climate Change (IPCC, 1996). From the seasonal data on type and quantity of feed and fodder fed to lactating and dry crossbred, local cows and buffaloes and gross energy intake was calculated as applied by Karunanithi (2004) (Appendix-VI).

Using the calculated methane emission factor, the methane emission per litre of milk production on farm households was worked as follows :

$$\text{Methane Emission/litre of milk} = \frac{\sum_i e_{ij} n_{ij}}{\text{MP}}$$

Where,

i = Crossbred, local cows and buffaloes,

j = Lactating and dry,

e = Emission factor,

n = Number of animals on sample farm, and

MP = Milk production on sample farm (litres).

c) Breeding practices

The breeding practices followed by the farmers affect the genetic potential of the animals and hence, have long-run implications for sustainability of dairy farming. With the use of low quality germplasm, the productive breeds getting progressively diluted and face degeneration. In recent years, several breeds have been reduced in number due to neglect and lack of concentrated breeding efforts. Such a loss of animal genetic diversity puts in jeopardy the sustainability of animal agriculture and the ability of the sector to respond to changing environmental conditions. Good breeding practices are therefore, essential pre-requisite for bringing genetic improvement of animals and thereby improving the productivity and sustainability of animals.

To examine whether the breeding practices in the study area are congenial from sustainability angle, some pre-decided questions were asked to dairy farmers regarding to breeding practices followed by them (For detailed questionnaire see the Appendix-V). For instance, in case of natural service whether selected or scrub was used, in case of A.I. whether service of trained person is taken or not, etc.

These practices were scored according to their implications for sustainability – the lower score for worst practice. After converting raw scores into standard scores a composite index was calculated from these standard

scores and was used for further analysis of ecological sustainability of the dairy farming.

Step-II : Assigning of Scores

After quantifying the indicators in each of the three dimensions, viz., economic, social and ecological dimension, scores were assigned to the indicators, that is, the actual quantified value of each indicator was converted into its respective scores following the procedure described as under :

For each indicator two threshold values were identified, viz. upper threshold (UT) and lower threshold (LT). The upper threshold indicated the ideal state while the lower threshold the minimum desired level for sustainability. These threshold values identified for each indicator on the basis of economic logic / scientific evidence / review of literature / conventional wisdom are presented in Table 3.3.

If the value of selected indicator has positive effect on sustainability then actual value (A) of indicator \geq upper threshold was given full score and actual value of indicator \leq lower threshold given zero score. Value in-between UT and LT was scored as follows:

$$(A - LT) / \frac{UT - LT}{(\text{Maximum score})}$$

If the value of selected indicator has negative effect on sustainability then, actual value of indicator \geq upper threshold was given zero score and actual value of indicator \leq lower threshold given full score. Value in-between UT and LT was scored as follows:

$$\text{Maximum score} - (A - LT) / \frac{UT - LT}{(\text{Maximum score})}$$

Step-III : Construction of Index

Using the scores assigned to the quantitative values of each indicators, index was constructed for each dimension (economic, social and environmental) and an overall index incorporating these three dimensions.

Table 3.3 Threshold values of indicators.

Indicators	Lower Threshold	Upper Threshold
Production cost	Least cost of the milk production in the sample households	Average selling prices of milk
Productivity of inputs		
a) Labour productivity	Minimum wage rate of Rs. 73 per day	Average productivity of top ten sample households
b) Capital productivity	Rate of interest on fixed deposit (9%)	Ideal rate of return (20%) on dairy
c) Feed productivity	0.45 lit./kg of dry matter	1 lit./kg of dry matter
Family labour income as a percent of monthly per capita consumption expenditure	0 percent	100 percent
Women empowerment index	0	100
Drudgery of work		
a) Sharing of burden among number of person in each activity	0	100
b) Carrying of weight/load	5kg/km	25 kg/km
c) Days off work affordable by main worker	One day off per week (52days)	One day off per month (12 days)
Use of dung as fuel to manure (%)	0 percent	100 percent
Enteric methane emission	Minimum methane emission in study area = 26.26 gm/lit of milk produced	Average methane emission in the study area = 42 gm/lit of milk
Breeding practices (index)	0	100

Individual dimension

The index for individual dimensions was framed in two ways :

(i) Assigning equal weights : The index was constructed on 100 point scale for each dimension and equal weights were assigned to each indicator of the respective dimension.

(ii) Assigning weights based on expert opinion : The weights to each dimension and indicator were assigned on the basis of expert opinion of 50 scientists of National Dairy Research Institute (NDRI) as well as from other research organizations in India. Based on average expert opinion, 46 percent weight was given to economic dimension, 30 percent to social dimension and 24 percent to environmental dimension. The alternate procedure did not make any difference to the minimum obtainable scores (=0) but changed the maximum obtainable score for each indicator. The detail of weighting procedure is as given in Table 3.4.

Overall Sustainable Dairy Farming Index (SDFI)

Finally, all the aspects of sustainability were weighted in overall Sustainable Dairy Farming Index (SDFI), i.e. into an overall figure that indicates farm sustainability or the livelihood of finding a successor for the farm.

The simple solution would be, to add up the values of each dimension. This would, however, neglect the fact that a minimum of each indicator appears necessary to achieve overall sustainability. It is difficult to imagine that a farm without any economic sustainability would survive, even if full environmental and social sustainability is given. Vice versa, an economically and socially viable farm could not be called sustainable if it caused major ecological damage. Therefore, the multiplicative sustainability package was used.

$$\text{SDFI} = \log (a*b*c)$$

Table 3.4 Assigning the weights to components and indicators.

Dimensions	Scores		Indicators	Scores	
Components	Equal Weights (Total 300)	Experts' Weights (Total 300)		Equal weights (Total 300)	Experts' Weights (Total 300)
Economic	0-100	0-138	Production cost	0-50	0-50
			Productivity of inputs	0-50	0-88
			a) Labour productivity	0-17	0-27
			b) Capital productivity	0-17	0-29
			c) Feed productivity	0-16	0-32
Social	0-100	0-90	Family labour income	0-33	0-29
			Women empowerment	0-34	0-28
			Drudgery of work	0-33	0-33
			a) Sharing of burden among number of person in each activity	0-11	0-11
			b) Carrying of weight/load	0-11	0-11
			c) Days off work affordable by main worker	0-11	0-11
Ecological	0-100	0-72	Use of dung: 0-33	0-33	0-33
			Enteric methane emission: 0-33	0-33	0-17
			Breeding practices: 0-34	0-34	0-22

Where,

SDFI = Sustainable Dairy Farming Index

a = Economic dimension of sustainability,

b = Social dimension of sustainability and

c = Ecological dimension of sustainability.

The full scores in each aspect of sustainability would result in a maximum of SDFI=6, while, minimum would be SDFI=0. To separate sustainable dairy households from non sustainable households, the households were grouped into three categories based on value of SDFI, i.e. household with SDFI < 3 were considered as low sustainable, $3 \leq \text{SDFI} < 5$ were considered as moderately sustainable while, households with value of SDFI ≥ 5 were considered highly sustainable.

3.4.4 Determinants of Sustainability of Dairy Farm

Multiple regression analysis has been carried out to know the factors affecting the sustainability of dairy farming⁵. The computed Sustainable Dairy Farming Index (SDFI) was regressed on explanatory variables. A list of these variables is as follows:

$$\text{SDFI} = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10})$$

Where,

X_1 = Ratio of crossbred cows and buffaloes to local cow

X_2 = Milk productivity of household (lit.)

X_3 = Proportion of milch animals up to III lactation (%)

X_4 = Marketed surplus of household (%)

X_5 = Size of operational land holding (ha)

⁵ Ideally in case where dependent variable is either censored on lower end or upper end, Tobit model should be used. However, in this case no censoring was occurred and hence ordinary least squares method was used.

X_6 = Per animal area under fodder crops (ha)

X_7 = Proportion of expenses on concentrates to total feed expenses (%)

X_8 = Proportion of curative veterinary expenses to total vet. expenses (%)

X_9 = Education

X_{10} = Extension contact

The *a-priori* logic for selection of these variables is:

Ratio of crossbred cows and buffaloes to local cow: The variable captures the effect of herd composition on the sustainability of farm. The productivity of crossbred cow and buffalo, in general, is higher and thus, it is expected that higher the number of crossbred cow and buffalo in proportion to local cow in the herd, farm will be economically more sustainable.

Milk productivity of household is a proxy for the quality of dairy animals reared by the farmer. Households with high milk productivity are expected to be more profitable while, low productivity will have adverse impact on profitability and ultimately on sustainability.

Proportion of milch animals up to IIIrd lactation The milk production of milch animals generally increases upto third lactation. It is thus hypothesized that higher the proportion of milch animals up to IIIrd lactation has positive effect on sustainability

Marketed surplus of household: This variable captures the commercial orientation of the farm. Surplus output from small-scale farming is closely linked to higher productivity, greater specialization, and higher income. Further commercialization leads to the separation of households' production decisions from their consumption decisions, supporting food diversity and overall stability.

Size of Operational Land holding: Economies of scale may be significant on larger farms and thus the sign on the coefficient of the farm size variable is hypothesized to be positive. Large farmers were postulated to be more sustainable as they had better access to resources.

Area under fodder crops per animal (hec.) attempts to capture year round availability of green fodder from own sources. The higher the area under fodder crops, the higher will be availability of fodder and, therefore, will increase the productivity of animals. Thus, this variable has positive association with dairy farm sustainability.

Proportion of variable expenses on concentrates feed is the most important item of the variable expenses. Among three types of feed, viz., dry fodder, green fodder and concentrates, higher use of concentrates leads to better feed consumption efficiency of animals. Therefore, it has positive effect on sustainability.

Proportion of curative veterinary expenses to total veterinary expenses : Total veterinary expenses include curative and preventive expenses. Preventive health procedures in veterinary medicine involve parasite control, neutering and annual vaccination and health checkups. This combination of good preventative health protocol can help maximize the potential life span and quality of animal lives and thereby improve the sustainability. Therefore, it is expected that higher the ratio of curative expenses to total veterinary expenses, lower will be the sustainability.

Education : It is expected that a higher level of education enhances a farmer's knowledge and awareness about improved dairy farming practices and has manifold effect on communication behaviour and general awareness, and make the farming more profitable and convenient. Thus, the level of education is expected to be positively related to sustainability. For this variable, average education score of members above 14 years of age was taken.

Extension contact: This variable shows the role of extension agencies in transferring sustainable dairy farming practices to the farmers. Extension contact is directly related to sustainability of dairy farming. This is because extension education enhances farmer's access to technological learning and improved production inputs that will lead to increased productivity. Thus farmers deprived of access to extension services are expected to be have less sustainable dairy farms.

4. GENERAL DESCRIPTION OF THE STUDY AREA

This Chapter gives an overview of the physiographic and socio-economic features of Rajasthan state, in general and sample district of Jaipur, in particular, to facilitate better understanding of the results of the study that are presented and discussed in the next chapter.

4.1 GEOGRAPHICAL LOCATION OF RAJASTHAN

The state of Rajasthan is located in north - west India between 23°4' and 30°11' north latitude and 69°21' and 78°17' east longitude. The Tropic of Cancer passes through its southern tip in the Banswara district. The state has a geographical area of 342,239 square kilometers. Presently there are 32 districts, 188 sub-divisions, 241 tehsils, 37889 inhabited villages and 222 towns in Rajasthan (DES, 2004). It is bounded by Pakistan on the west and northwest, by the state of Punjab and Haryana on the north, by Uttar Pradesh and Madhya Pradesh in east and southwest, and on the southwest by the state of Gujarat (Fig. 4.1).

Fig. 4.1 Location of Rajasthan in the map of India.



In the west, Rajasthan is relatively dry and infertile; this area includes some of the Thar Desert, also known as the Great Indian Desert. In the southwestern part of the state, the land is wetter, hilly and more fertile.

The Aravali mountains stretching diagonally across the state from the South-West to North-East separate the desert and semi-desert areas to the West from the sub-humid areas in the East.

4.2 CLIMATE

The climate of Rajasthan is characterized by great extremes of temperature. The diurnal range of temperature is very high. Days are hot and the nights are cold. The desiccated land becomes more parched and dry during the summer owing to the scorching heat of the sun and the temperature reaches the peak of 49°C. But, in the night, the temperature falls to a great extent and becomes less than 20°C. During winter it may even reach the freezing point 0°C at night. On an average, winter temperatures range from 8° to 28° C (46° to 82° F) and summer temperatures range from 25° to 46° C (77° to 115° F).

The average rainfall of Rajasthan is 574 mm but it varies significantly across different regions. In the western Rajasthan, the average annual rainfall ranges from less than 100 mm in north-western part of Jaisalmer (lowest in the state) to over 400 mm in Sikar, Jhunjhunu and Pali regions and along the western fringes of the Aravali range. In the eastern region, the rainfall ranges from 550 mm in Ajmer to 1020 mm in Jhalawar. Mount Abu (Sirohi district) in the southwest, receives the highest rainfall in the state (1638 mm). The annual total spatially averaged rainfall is highly variable and it is most erratic in the western region with frequent dry spells, punctuated occasionally by heavy downpour in some years associated with the passing low pressure systems over the region. About 90 percent of the rainfall in the state occurs during the onset of southwest monsoon, which has its beginning in the last week of June in the eastern parts and may last till mid-September. However, due to erratic and uncertain nature of monsoon, Rajasthan is often subjected

to famines and scarcity. Draught is a recurrent phenomenon in the state. In every 100 years, there are 7 years of acute drought, 27 years of scarcity, 63 manageable years and only 3 normal years (Singh *et al.*, 2004).

4.3 PHYSIOGRAPHIC FEATURES OF RAJASTHAN

Three main physiographic regions can be delineated in the State. To the west of Aravali range, there are 12 districts¹ covering approximately 61 percent of the area. The climate here is characterized by low and erratic rainfall, extremes of diurnal and annual temperatures, low humidity and high wind velocity. To the east of Aravali, the climate is semi-arid to sub-humid. The 14 districts² in this region are characterized by more or less the same extremes in temperatures, relatively lower wind velocity and high humidity with better rainfall. The remaining area falls within the Aravali range with high rainfall, hilly topography and forest cover and is classified as a tribal area.

The soil and vegetation of Rajasthan alters with its wide-ranging topography of the state and the availability of water. The varied kinds of soils available in Rajasthan are mostly sandy, saline, alkaline and chalky (calcareous). Other soil types such as, clay, loamy, black lava soil and nitrogenous soils are also found.

The ground water level is very low due to over-exploitation. Water level is available only at a depth of 30 to 61 m. The limited, erratic rainfall averaging 360 mm per year allows the growth of scanty, shrub – like thorny vegetation. Grasses and species like Khejri (*P. cineraria*) grow in the regions where little water is available. However, food crops are grown in the plains that are drained by the rivers and streamlets owing to the alluvial and clay soil deposits.

The districts of Jaisalmer, Bikaner, Barmer, Jalore, Jodhpur, Ganganagar, Sirohi, Jhunjhunu, Pali and Sikar have alkaline and saline soils with a calcareous base. There is some nitrate concentration in the soil of

¹ Jalore, Barmer, Jaisalmer, Pali, Jodhpur, Nagaur, Bikaner, Ganganagar, Hanumangarh, Churu, Sikar and Jhunjhunu.

² Bharatpur, Dholpur, Dungarpur, Karauli, Swai Madhopur, Tonk, Kota, Bundi, Baran, Jhalawar, Bhilwara, Chittorgarh, Banaswara and Dausa.

these regions. Due to lack of water availability vegetation comprises of only thorny bush and cactuses. There is only seasonal vegetation such as a few grass species, shrubs and dwarf trees. In these arid regions, land is dry but not infertile. Hence, in irrigated areas Rabi crops like, wheat and mustard are grown; during the monsoon kharif pulses and pearl millet are grown.

The whole district of Ganganagar consists of alluvial and aeolian soils as it is flooded by the Ghaggar river. The Gang canal and Bhakhra canal enable the flow of water and hence, this area is filled with lush vegetation and food crops consisting of maize, clusterbeal, sesamum, wheat, mustard, gram, fruits and so on. The four districts of Dausa, Tonk, Jaipur and Ajmer are watered by river Banas and its tributaries and thus, the fertile soil sustains mixed xerophytic and mesophytic vegetation. Field crops like barley, gram, wheat, mustard are grown in the rabi season.

The districts of Bharatpur, Alwar and Dhaulpur and the northern region of Sawai Madhopur district are flooded by the river Ghambhiri and Banganga. This region is the repository of alluvial, clay and loamy soils.

The Bhilwara district and the major parts of Udaipur district, Chittaurgarh district, Sirohi district and the tract of Aravali Hills form a part of inter-mountain plateau, which consists of dark- lava soils. Major cash crops like cotton and sugarcane are grown in this black soil region. Other food crops are also grown. The Hadauti plateau includes the districts of Baran, Bundi, Jhalawar and Kota, which have black soil. This region is fertile owing to the presence of the Chambal River and its distributaries. Here, cotton, sugarcane and opium are grown.

4.4 DEMOGRAPHIC PROFILE

Rajasthan harbors human population of nearly 56.51 million (Census, 2001) accounting for nearly 5.5 percent of India's population (Table 4.1) whereas, the state is having 10.41 percent of geographical area of the country. Therefore, estimated density of population is almost half (165 persons/sq.km) than the all-India density (325 persons/sq.km). The sex ratio in Rajasthan (922) is even lower than the all-India average of 933, reflecting

poor social status of women in the state. The wide disparities in female literacy rate in Rajasthan (44.34%) vs. average all-India average (53.70%) further substantiates this fact. Interestingly, the male literacy rate in Rajasthan is higher than average male literacy in India.

The extent of urbanization is low in Rajasthan as more than 3/4th of its population is in rural areas. The working population forms about 42.09 percent and remaining constitutes the non-working group.

Table 4.1 Distribution of human population in Rajasthan.

('000)

S. No.	Particular	Rajasthan	India
1.	Total Population	56507	1028737
	Male	29420	532223
	Female	27087	496514
	Rural	43293 (76.62)	742491 (72.20)
	Urban	13214 (23.38)	286120 (27.80)
2.	Density of Population Sq.km ⁻¹	165	325
3.	Sex Ratio (No. of Female per 1000 of Males)	922	933
4.	Literacy rate (%)	61.03	64.80
	Male	76.46	75.30
	Female	44.34	53.70
5.	Total Workers	23781 (42.09)	402235 (39.10)
	Main	17430 (30.85)	313005 (30.40)
	Marginal	6351 (11.24)	89230 (8.7)

Figures in parentheses indicate the percentages to the total.

Source: Directorate of Economics and Statistics, Jaipur Rajasthan and Population Census 2001.

4.5 LAND UTILISATION PATTERN AND LAND HOLDING

The arable land (the net area sown plus the current & fallow lands) in Rajasthan is estimated at 21013 thousand hectares that is 61.33 percent of

the total reported geographical area (Table 4.2). Around 2661 thousand hectares (7.77%) of the total area is under forests while land put to non-agricultural uses is estimated at 1776 thousand hectares (5.18%). The cultivable waste land, barren & unculturable land together with permanent pastures & other grazing land account for over 25 percent of the reporting area indicating a great scope for bringing additional area under cultivation. The cropping intensity is about 127 percent and only 33.68 percent of the gross crop area is under irrigation.

Table 4.2 Land utilisation pattern in Rajasthan (2004-05).

Land Utilisation	Area (‘000 hac.)
Total geographical area	34265
Reporting Area for land utilization	34266
Forest	2661 (7.77)
Area under non agricultural uses	1776 (5.18)
Barren and uncultivable land	2491 (7.27)
Permanent Pasture and other grazing land	1709 (4.99)
Land under miscellaneous tree crops & groves	14 (0.04)
Cultivable Waste Land	4603 (13.43)
Fallow land other than current fallow	2162 (6.31)
Current Fellow	2302 (6.72)
Net Area Sown	16549 (48.30)
Total cropped area	21062 (61.47)
Cropping Intensity (%)	127.27
Net irrigated area	5880
Gross irrigated area	7093
Net irrigated area as a percentage of net shown area	35.53
Gross irrigated area as a percentage of gross cropped area	33.68

Figures in parentheses indicate the percentages to geographical area

Source: Directorate of Economics and Statistics, Jaipur Rajasthan

The land holding pattern indicates the degree of skewness in the ownership of land assets and the degree of rural inequality in Rajasthan. As per the Agricultural Census Report (2001), large holdings account for nearly 7.91 percent of total number of land holdings, while, the cumulative share of

marginal and small landholdings is nearly 52.57 percent (Table 4.3). However, large landholders control a disproportionate share (39.46%) of the total landholding area as against only 12.42 percent owned by marginal and small holders.

Table 4.3 Land holdings in Rajasthan by size (2001)

Type of land holding	No. of holdings (in '000)	Area ('000 ha)	Average size of holding (Hectare)
Marginal Holdings (Less than 1 ha)	1849 (31.78)	894 (4.21)	0.48
Small holdings (1-2 ha)	1210 (20.79)	1744 (8.21)	1.44
Semi-medium holdings (2-4 ha)	1200 (20.62)	3416 (16.07)	2.85
Medium holdings (4-10 ha)	1100 (18.90)	6811 (32.05)	6.19
Large holdings (> 10 ha)	460 (7.91)	8386 (39.46)	18.21
All holdings	5819 (100.00)	21251 (100.00)	3.65

Figures in parentheses indicate the percentages to the total

Source: www.agricensus.nic.in

4.6 CROPPING PATTERN

Rajasthan's crop production displays distinct features in its cropping pattern. The principal Rabi crops are barley, wheat, gram, pulses and oil seeds (Table 4.4 and Fig.4.2). The major oil seeds are rapeseed and mustard. The Kharif crops grown here include pearl millet, pulses, sorghum, maize and groundnut. Cereal crops occupied around 42.84 percent of the gross cropped area, while the corresponding figures for oilseeds and pulses was 15.53 and 19.69 percent, respectively in the state. The regions that are highly irrigated or receive abundant water supply are utilized for the cultivation of improved high-yielding varieties of rice. Some places of Rajasthan (e.g. Ganganagar, Hunumangarh and hilly track of Aravali region), which have

black soils nurture the growth of major cash crops like cotton. In some regions tobacco is also grown. Apart from this crops an assortment of fruits and vegetables are also grown in Rajasthan in the local gardens and some fertile regions. These fruits include oranges, guavas, lemon, pomegranates and mangoes. Rajasthan soil is also suited for the growth of some spice plants, especially red, hot chilies. These chilies give Rajasthan its distinct flavor. Other spices are cumin seeds and methi.

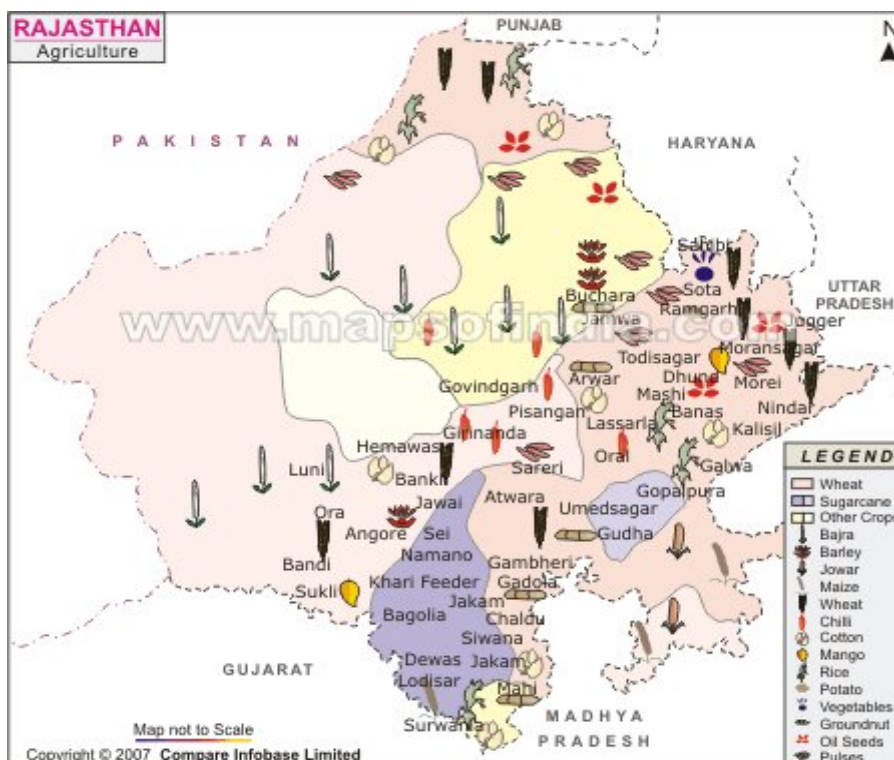
Table 4.4 Area under important crops in Rajasthan in the trinneium ending 2003-04 to 2005-06.

Sl. No.	Crops	Area (In '000 Hac.)	Production (In '000 Tonnes)*
1.	Gross cropped area	21475	--
2.	Bajra	5126	3937
3.	R. & Mustard	3546	3709
4.	Guar	2529	707
5.	Wheat	2079	5816
6.	Moth	1464	490
7.	Maize	1052	1478
8.	Gram	1078	653
9.	Moong	792	360
10.	Soyabean	620	311
11.	Jowar	633	321
12.	Cotton	418	983
13.	Groundnut	304	476
14.	Barley	183	431
15.	Rice	103	162
17.	Total Cereals	9199	12358
18.	Total oilseeds	3995	5167
19.	Total Pulses	4229	1505

* Cotton production is in bale = 170 kg.

Source: Directorate of Economics and Statistics, Jaipur Rajasthan

Fig 4.2 Major crops in Rajasthan.



Source : www.mapsofindia.com

4.7 ANIMAL HUSBANDRY

The sheer 'vastness' in terms of land area, human and livestock population on one hand, and 'diversity' with regard to physical, environmental and biological resources, on the other, put a distinctive stamp on agro-ecosystem of Rajasthan as something very different from others. The inhospitable climate of arid-ecosystem and impoverished fragile soils coupled with scarce water resources make the sustainable development of the state a challenging task though not formidable. In such a situation livestock provides an instrument to insulate the income of rural poor and proves the source of livelihood in the state.

4.7.1 Livestock Population:

Rajasthan ranks second in the country (after Uttar Pradesh) which approximately 11 percent (49.14 million) of total livestock population in India. The dominant livestock species in the state is ovines (sheep and goat), which

accounting for over 54 percent of the livestock in Rajasthan (Table 4.5). In fact, the state has highest number of heads of these small ruminants in the country. The next important species is bovines (21-30 million) constituting 43.34 percent of the total population.

The population of cows and buffaloes is, about the same (50.95 and 50.05%, respectively). Among the cattle population, the indigenous breeds predominate (95.73%) and the adoption of crossbreeding is of small magnitude. Rajasthan is the home tract of some of the nationally recognized breeds of milch and draught cattle like Rathi, Tharparkar, Gir, Kankrej, Nagauri, Malvi & Haryana.

Table 4.5 Livestock population of Rajasthan (2003 Census).

(In Nos.)

Sl. No.	Particulars	Rajasthan
1.	Crossbred Cattle	463714 (0.94)
2.	Indigenous Cattle	10389778 (21.14)
3.	Total Cattle	10853492 (22.08)
4.	Buffaloes	10446167 (21.26)
5.	Total Bovines	21299659 (43.34)
6.	Sheep	10031822 (20.41)
7.	Goats	16808030 (34.20)
8.	Pigs	337763 (0.69)
9.	Camels	498023 (1.01)
10.	Others	170692 (0.35)
11.	Total Livestock	49145989 (100.00)
12.	Livestock Density (Per Sq. km.)	213

Figures in parentheses indicate the percentages to the total

Source: Department of animal Husbandry, Govt. of Rajasthan, Jaipur

4.7.2 Livestock Holding:

Small-scale mixed crop-livestock farming is the most common and dominant form of animal husbandry in Rajasthan. For small and marginal farmers animal husbandry based on family labour and residues/byproducts of homegrown crops continue to be a substantial source of income and employment.

Marginal and small farm households that comprise around 57 percent of the total households, share 54.64 percent of cattle, around 55 percent of buffaloes, 57 percent of sheep and goats, over 81 percent of pigs and 89 percent of poultry (Table 4.6).

As the smaller land holdings (up to 2 ha) rear dominant proportion of livestock; the density of livestock holding (no. of heads/100 ha of land holding) is inversely related with the size of holding. The per hectare livestock are highest in marginal category followed by small, semi-medium, medium and large farm sizes (Table 4.7). Interestingly, the ovine population per 100 hectares is as high as 521 in marginal category, while for large category it is only 58 per 100 hectares of operational holdings.

4.7.3 Milk Production and Productivity

The milk production and productivity of different dairy animals in Rajasthan is presented in Table 4.8. The state produces approximately 8.31 million tonnes of milk per year, which is about 9 percent of total milk production in the country. The milk productivity of buffaloes was 4.41 litres/day, higher than the average yield of cows (2.99 lit.). Hence, in the total production, buffalo milk has the highest share of nearly 60.95 percent followed by cattle (28.11%) and goat (10.94%) milk.

The crossbred cows were more than twice as productive as local cattle (average 6.07 and 2.86 litres/day, respectively) but due to much larger population of indigenous cows, only 8 percent of the cow milk was produced by crossbred cattle.

Table 4.6 Distribution of livestock across size group of land holdings in rural Rajasthan, 2002-03.

(Percent)

Size of Holding		Landless/near landless (<0.002 ha)	Marginal (0.002-1.0 ha)	Small (1.0-2.0 ha)	Semi-Medium (2.0-4.0 ha)	Medium (4.0-10.0 ha)	Large (>10.0 ha)	All
Cattle		0.68	39.91	14.73	16.63	16.14	11.91	100.00
Adult	Male	0.40	64.87	14.87	12.18	6.07	1.61	100.00
	Female	0.79	32.70	15.03	17.74	19.01	14.72	100.00
	All	0.67	43.06	14.98	15.95	14.85	10.50	100.00
Young stock	Male	0.55	36.14	12.19	22.98	17.83	10.31	100.00
	Female	0.84	30.62	15.65	14.66	19.83	18.40	100.00
	All	0.72	32.89	14.22	18.12	19.01	15.05	100.00
Buffalo		0.44	36.05	18.85	22.79	15.97	5.90	100.00
Adult	Male	3.01	41.03	10.93	28.61	4.29	12.13	100.00
	Female	0.43	36.45	19.29	23.01	15.78	5.04	100.00
	All	0.53	36.63	18.96	23.23	15.32	5.32	100.00
Young stock	Male	0.00	33.47	17.62	20.12	23.66	5.14	100.00
	Female	0.40	35.69	19.06	22.71	14.80	7.34	100.00
	All	0.30	35.15	18.71	22.08	16.96	6.80	100.00
Large heads other than cattle & buffalo like camel & horse		2.44	25.68	15.58	11.38	19.42	25.51	100.00
Sheep and goat		1.16	46.01	11.16	12.77	14.87	14.03	100.00
Pigs		18.64	81.36	0.00	0.00	0.00	0.00	100.00
Rabbits		0.00	100.00	0.00	0.00	0.00	0.00	100.00
Poultry		1.23	79.17	9.96	8.69	0.43	0.54	100.00
Number of households (00)		10798 (15.39)	28784 (41.02)	11129 (15.86)	9609 (13.69)	7058 (10.06)	2993 (3.96)	70175 (100.00)

Source: Own estimates based on Livestock Ownership Across Operational Land Holding Classes in India, 2002-03, National Sample Survey Organisation, Govt. of India, Report No.493.

Table 4.7 Livestock per 100 hectare of holding in Rajasthan by size group of land holdings, 2002-03.

Size of Holding		Marginal (< 1ha)	Small (1-2 ha)	Semi-medium (2-4 ha)	Medium (4-10 ha)	Large (>10 ha)	All size Classes
Total Cattle		201	87	57	35	22	37
Adult	Male	72	20	9	3	1	8
	Female	78	41	29	19	13	17
	All	150	61	38	22	14	25
Young stock	Male	23	09	10	5	2	5
	Female	28	17	9	8	6	7
	All	51	26	19	13	9	12
Total buffalo		155	95	67	29	9	31
Adult	Male	4	1	2	0	0	1
	Female	92	57	39	17	5	18
	All	96	58	41	17	5	19
Young stock	Male	14	9	6	4	1	3
	Female	45	28	19	8	3	9
	All	59	37	25	12	4	12
Large heads other than cattle and buffalo		5	4	2	2	2	1
Sheep and goat		521	146	98	71	58	82

Source: Own estimate based on Report on Land and Livestock Holdings, 2002-03, National Sample Survey Organisation, Govt. of India.

Table 4.8 Milk production and productivity of bovine in Rajasthan (2004-05).

Species	Rajasthan	
	Average Yield/animal (l/day)	Production ('000 tons)
Indigenous cattle	2.862	2148 (25.85)
Cross bred cattle	6.070	188 (2.26)
Buffalo	4.412	5065 (60.95)
Goat	0.588	909 (10.94)
Total milk production	-	8310 (100.00)

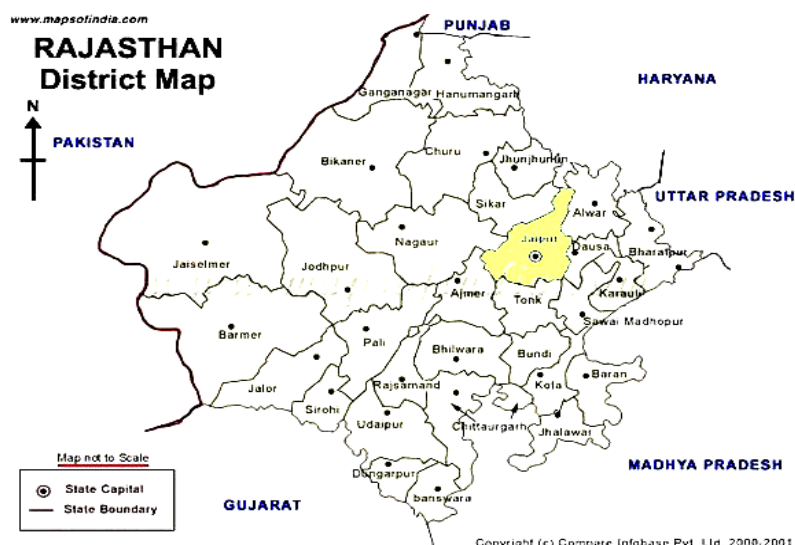
Source : State Department of Animal Husbandry, Jaipur, Rajasthan.

Figures in parentheses indicate the percentages to the total

4.8 PROFILE OF SAMPLE DISTRICT

Geographical location: Jaipur, the capital city of Rajasthan also known as 'Pink City' is located between 26°23' and 27°51' north latitude and 74°55' and 76°50' east longitude covering a geographical area of 11151 sq.km. The district is situated at mean elevation of 122-183 Miter Above Mean Sea Level. It is surrounded by Mahendragarh district of Haryana and Sikar district of Rajasthan in north, Tonk district in south, Alwar, Swai Madhopur and Dausa in east and Nagaur and Ajmer district in west (Fig.4.3).

Fig. 4.3 Location of Jaipur in the map of Rajasthan.



Climate: The climate of Jaipur district is dry and is subject to extreme of cold and heat at various places. The minimum and maximum temperatures recorded in the district vary from 8.0°C to 48 °C. The normal annual rainfall is 55.64 cms. There are 13 tehsils and 13 Panchayat Samities and 14 towns in the district. The hillock and mountains of Aravali range cover northern part of Jaipur district. Bangana and Sabi are the important rivers. Bangana is major source of water supply to Jaipur city. The district is also site of world famous natural salt lake 'Sambhar', which is largest source of salt in the country.

Demographic profile: Jaipur district housed a population of about 5251 thousand, which formed about 9.29 percent of state human population (2001). The density of population in Jaipur (471 person/sq.km) is more than double that of Rajasthan, but the sex ratio is even worse than the state level, being only 897 in the district (Table 4.9). However, the literary rate (overall, male, female) is comparatively better in the district due to large urban population. The incidence of urbanization is quite impressive, the district has 50.64 percent of its total population as urbanities as compared to 23.38 percent in the state. With respect to the percentage of working population to the total population of the district, it was significantly lower than the state and was 35.48 percent.

Land utilisation pattern and land holding: Jaipur district with a total geographical area of 1105 thousand hectares is the 10th largest district in the state, sharing 3.22 percent of state's area and 4.05 percent of net sown area (Table 4.10). The district has a net sown area of 6.71 thousand hectares and about half of this is sown more than once. Hence, the cropping intensity is 150 percent. With about 13 percent of the area under barren and uncultivated land (4.53%) cultivated waste land (3.09%) and permanent pasture and other grazing land (6.96%) indicating that there exists good potential to bring more area under sowing. However, as pointed out earlier, the extent of urbanization is higher in the capital district, and this may further put pressure to expand the area for non-agriculture uses.

Table 4.9 The distribution of Human population in Jaipur.

('000)

Sl. No.	Particular	Jaipur
1.	Total Population	5251 (100.00)
	Male	2768 (52.71)
	Female	2483 (47.29)
	Rural	2592 (49.36)
	Urban	2659 (50.64)
2.	Density of Population Sq.km ⁻¹	471
3.	Sex Ratio (No. of Female per 1000 of Males)	897
4.	Literacy rate (%)	70.63
	Male	83.58
	Female	56.18
5.	Total workers	1863 (35.44)
	Main	1583 (84.97)
	Marginal	280 (15.03)

Source : Directorate of Economics & Statistics, Jaipur, Rajasthan.
 Figures in parentheses indicate the percentages to total population.

Table 4.10 Land utilisation pattern in Jaipur (2004-05).

('000 ha)

Land Utilisation	Area	Percentage to Total Geographical area
Total geographical area	1105	100.00
Reporting Area for land utilization	1106	100.05
Forest	81	7.35
Area under non agricultural uses	81	7.29
Barren and uncultivable land	50	4.53
Permanent Pasture and other grazing land	77	6.98
Land under miscellaneous tree crops & groves	1	0.08
Cultivable Waste Land	34	3.09
Fallow land other than current fallow	56	5.03
Current Fellow	55	5.02
Net Area Sown	671	60.68
Total cropped area	1007	91.09
Cropping Intensity (%)	150.11	
Net irrigated area	329	
Gross irrigated area	417	
Net irrigated area as a percent of net sown area	32.67	
Gross irrigated area as a percent of gross cropped area	41.41	

Figures in parentheses indicate the percentages to total cropped area
 Source: Directorate of Economics and Statistics, Jaipur Rajasthan

The land holding pattern in Jaipur district also indicates the degree of skewness in the ownership of land assets. The overall average size of holding in the district is lower than the corresponding state figure. The small and marginal holdings together account for more than 56 percent of total holdings, while, these holdings have only 18.40 percent of total area. Contrary to this, the large holdings account merely 4 percent of total number of land holdings, whereas, the area under these holdings is 22.69 percent of the total area (Table 4.11).

Table 4.11 Land holdings in Jaipur by size.

Type of land holding	No. of holdings (in '000)	Area ('000 ha)	Average size of holding (Hectare)
Marginal Holdings (Less than 1 ha)	91.20 (31.60)	45.15 (5.64)	0.49
Small holdings (1-2 ha)	70.63 (24.48)	102.06 (12.76)	1.44
Semi-medium holdings (2-4 ha)	71.13 (24.65)	203.50 (25.44)	2.86
Medium holdings (4-10 ha)	44.81 (15.53)	264.45 (33.57)	5.99
Large holdings (> 10 ha)	10.80 (3.74)	180.63 (22.59)	16.72
All holdings	288.58 (100.00)	799.78 (100.00)	2.77

Figures in parentheses indicate the percentages to the total

Source: Website of Agricultural Census Division, Ministry of Agriculture, New Delhi

Cropping Pattern: Jaipur district presents a progressive picture of agricultural performance. Pearl millet has highest share (26.64 percent) of the gross cropped area (GCA), followed by wheat and gram with 15 and 6 percent of GCA, respectively (Table 4.12). Productivity of crops in the district is quite high compared to the state average, due to better irrigation and other agricultural infrastructure facilities. This is amply evident from the statistics that the share of Jaipur in Rajasthan's area under pearl millet, groundnut,

gram and wheat is 6.01, 19.08, 5.85 and 7.73 percent, respectively, although it accounts for much higher proportion of 12.55, 23.66, 7.36 and 8.07 percent of Rajasthan's production of these crops, respectively. Jaipur is highest producer of barley in the state producing 31.03 percent of the total barley production in Rajasthan. The district is also advanced in the production of rapeseed and mustard.

Table 4.12 Area under important crops in Jaipur (2004-05).

Sl. No.	Crops	Area (In Ha)	Production (Tonnes)	Percentage of state	
				Area	Production
1.	Gross cropped area	1006592	-	-	-
2.	Wheat	155445	460550	7.73	8.07
3.	Bajra	268113	376778	5.87	12.55
4.	Rapeseed and mustard	-	159630	-	4.14
5.	Barley	48655	129722	27.80	31.03
6.	Groundnut	54951	105773	19.08	23.66
7.	Gram	60526	56924	5.85	7.36
8.	Jowar	25141	9153	4.39	3.44
9.	Maize	5823	3835	0.56	0.30

Figures in parentheses are percentages to gross cropped area.

Source: Directorate of Economics and Statistics, Jaipur, Rajasthan

Animal husbandry

About 5 percent of the state livestock population (2.46 million) is in Jaipur district. It has 6.11, 3.04, 4.78, 3.18 and 10.31 percent of bovine, sheep, goats, camels and pigs, respectively, in Rajasthan (Table 4.13).

Out of 1.3 million bovine population, approximately 3/4th (0.89 million) are buffaloes and remaining are cows. The district has higher percent of crossbreds in the cattle population (16.37%) as compared to the state average of only 5 percent.

Table 4.13 Livestock population of Jaipur (2003 Census).

(In No.)

S. No.	Particulars	Jaipur	% to state population
1.	Crossbred Cattle	67499 (2.74)	14.56
2.	Indigenous Cattle	344734 (13.98)	3.32
3.	Total Cattle	412233 (16.72)	3.80
4.	Buffaloes	889461 (36.08)	8.51
5.	Total Bovines	1301694 (52.80)	6.11
6.	Sheep	305403 (12.39)	3.04
7.	Goats	803689 (32.60)	4.78
8.	Pigs	34815 (1.41)	10.31
9.	Camels	15845 (0.64)	3.18
10.	Others	3689 (0.15)	2.16
11.	Total Livestock	2465135 (100.00)	5.02
12.	Livestock Density (Per sq. km.)	144	

Figures in parentheses indicate the percentages to the total livestock.

Source: Department of Animal Husbandry, Govt. of Rajasthan, Jaipur

Jaipur is the highest milk producing district in the state and accounting for around 8.12 percent of state milk production. The contribution of the various species in the total milk production of Jaipur, is at variance with the state figure. Being a buffalo dominant region, of the total milk of 675 thousand tones, buffalo milk accounted for 487 thousand tonnes (72.15 percent), while cow milk shared about 129 thousand tonnes (19.11 percent). The perusal of Table 4.14 clearly shows that the buffaloes are more productive in the district than the state average.

Table 4.14 Milk production and productivity of bovine in Rajasthan and Jaipur (2004-05).

Species	Jaipur	
	Average Yield/animal (l/day)	Production ('000 tons)
Indigenous cattle	3.699	129 (19.11)
Buffalo	4.758	487 (72.15)
Goat	0.824	59 (8.74)
Total milk production	-	675 (100.00)

Figures in parentheses indicate the percentages to the total.

* Separate for local and crossbred cattle were not available.

5. RESULTS AND DISCUSSION

The results of the analysis are presented and discussed under following four major heads in tune with the objectives of the study :

- 5.1 Total factor productivity (TFP) growth in livestock sector : State level.
- 5.2 Sustainability index of livestock production : Zonal and district level.
- 5.3 Sustainability of dairy farming : Household level.
- 5.4 Determinants of sustainable dairy farming.

5.1 TOTAL FACTOR PRODUCTIVITY (TFP) GROWTH IN LIVESTOCK SECTOR : STATE LEVEL

The measurement of TFP growth involves estimation of output and input indices of production. These output and input indices are computed from the value of output and input, respectively. Therefore, before discussing the level and pattern of TFP growth in livestock sector in Rajasthan, the trends in value of output and input are discussed for a comprehensive understanding of the sources of growth and sustainability of livestock sector in the state.

5.1.1 Value of Output from Livestock : Composition and Growth

The quinquennial average value of output from livestock sector at current as well as constant prices and the decadal growth rates are given in Tables 5.1 and 5.2 and discussed as under :

5.1.1.1 Composition

Milk and milk products, meat and meat products, eggs, wool and hair, dung, draft power and other products are components of output from livestock sector. The composition and changes their in the value of output are discussed component-wise in declining order of their importance in total value of output.

Table 5.1 Total Value of output from livestock Sector and its Percentage Composition in Rajasthan (Quinquennial average).

(Value in Lakh Rs.)

Items/ Periods	1960-61 to 1964-65	1965-66 to 1969-70	1970-71 to 1774-75	1975-76 to 1979-80	1980-81 to 1984-85	1985-86 to 1989-90	1990-91 to 1994-95	1995-96 to 1999-00	2000-01 to 2004-05
At Current Prices									
Milk Group	12595 (46.87)	18252 (53.05)	29355 (55.60)	53295 (58.34)	93274 (55.98)	163091 (60.67)	272414 (60.25)	536718 (58.90)	872495 (61.51)
Meat Group	518 (1.93)	788 (2.29)	1175 (2.23)	2242 (2.45)	4314 (2.59)	7415 (2.76)	15039 (3.33)	42701 (4.69)	65241 (4.60)
Eggs	60 (0.22)	121 (0.35)	174 (0.33)	341 (0.37)	626 (0.38)	1229 (0.46)	2818 (0.62)	5420 (0.59)	8051 (0.57)
Wool & Hair	619 (2.30)	677 (1.97)	1263 (2.39)	1895 (2.07)	2645 (1.59)	4689 (1.74)	5106 (1.13)	7241 (0.79)	6799 (0.48)
Dung	3879 (14.43)	4320 (12.58)	9638 (18.26)	15115 (16.54)	28780 (17.27)	53240 (19.80)	93943 (20.78)	216919 (23.81)	299634 (21.12)
Draft power	9031 (33.60)	10040 (29.18)	10807 (20.47)	17881 (19.57)	35200 (21.12)	35732 (13.29)	58674 (12.98)	80734 (8.86)	141776 (9.99)
Others	172 (0.64)	208 (0.60)	381 (0.72)	589 (0.65)	1795 (1.08)	3434 (1.28)	4173 (0.92)	21483 (2.36)	24512 (1.73)
Total value	26874 (100)	34406 (100)	52793 (100)	91360 (100)	166634 (100)	268830 (100)	452167 (100)	911217 (100)	1418508 (100)
At 1993-94 Prices									
Milk Group	185721 (54.71)	162417 (52.23)	162865 (51.21)	196783 (54.17)	229610 (58.19)	260931 (60.89)	292543 (60.21)	386819 (58.99)	490431 (61.93)
Meat Group	10138 (2.99)	10224 (3.29)	9989 (3.14)	10988 (3.03)	13068 (3.31)	13677 (3.19)	19080 (3.93)	23415 (3.57)	31544 (3.98)
Eggs	358 (0.11)	487 (0.16)	600 (0.19)	939 (0.26)	1368 (0.35)	2007 (0.47)	3051 (0.63)	4396 (0.67)	5498 (0.69)
Wool & Hair	7295 (2.15)	7180 (2.31)	10078 (3.17)	8567 (2.36)	5927 (1.50)	6938 (1.62)	4713 (0.97)	5292 (0.81)	5704 (0.72)
Dung	89108 (26.25)	83827 (26.89)	87482 (27.51)	94616 (26.05)	98134 (24.87)	105000 (24.50)	105467 (21.71)	160706 (24.51)	192733 (24.34)
Draft power	45527 (13.41)	45987 (14.79)	45207 (14.22)	49298 (13.57)	42774 (10.84)	35883 (8.37)	57496 (11.83)	58345 (8.90)	52258 (6.60)
Others	1314 (0.39)	1047 (0.34)	1794 (0.56)	2046 (0.56)	3705 (0.94)	4088 (0.95)	3540 (0.73)	16787 (2.56)	13784 (1.74)
Total value	339460 (100)	310969 (100)	318016 (100)	363237 (100)	394585 (100)	428525 (100)	485890 (100)	655760 (100)	791952 (100)

Figures in parentheses are percentages of total value of output from livestock

Table 5.2 Growth trends of value of output from livestock sector and its components in Rajasthan at current and 1993-94 prices.

Item/Period	1960-61 to 1970-71	1970-71 to 1980-81	1980-81 to 1990-91	1990-91 to 2004-05	1960-61 to 2004-05
At Current Prices					
Milk Group	7.98	12.43	11.48	12.49	11.49
Meat Group	7.98	13.76	11.02	16.07	13.31
Eggs	12.85	13.66	14.24	11.62	13.42
Wool & Hair	1.98	11.28	9.40	2.77	7.07
Dung	4.80	10.76	12.75	12.16	12.29
Draft power	2.67	10.41	1.36	9.27	7.34
Others	7.20	12.40	13.05	2.51	-
Total	5.80	11.71	9.78	12.29	10.88
At 1993-94 Prices					
Milk Group	-1.66	3.81	2.44	5.26	2.68
Meat Group	0.04	1.78	2.17	5.02	2.87
Eggs	6.09	8.53	7.68	6.25	7.44
Wool & Hair	-0.41	-3.39	-0.21	1.94	-1.17
Dung	-0.63	1.34	1.31	5.76	1.86
Draft power	0.15	0.90	-2.11	-0.74	0.44
Others	1.92	3.77	2.87	-3.88	-
Total	-1.05	2.53	1.55	4.95	2.23

Milk group :

Milk and milk products constitute the lion's share in the value of output. In early 1960-61 it contributed nearly half (45.25%) of the value of output and this proportion increased to about two-third (65.38%) in 2004-05 (Fig. 5.1). Over the years, there has been a sustained increase in the share of milk group in the value of output at current prices (Table 5.1), however, in real terms (at constant prices base 1993-94 = 100) a marginal decline in the same occurred during the 60's. The decline in milk output in real terms, as observed

from the negative compound annual growth rate of real value of output from milk group during 1960-61 to 1970-71 (Table 5.2) led to the decline in its proportionate share in total value of output from livestock sector.

Dung :

After the milk group, the second highest share (17.57%) was of dung (Fig. 5.1). There is a large difference in the share of this component till the 90's in terms of current and constant prices. For instance, in the quinquennium ending 1964-65 the value of dung output was 14.4 percent in total value of output at current prices, but this was as high as 26.25 percent when both dung and total value of output are taken at constant prices, base 1993-94. This was so due to relatively very much higher prices of dung past 90's as compared to the earlier period¹.

Draft power :

Up to mid 80's, the animal draft power, which was the second largest component of livestock sector slipped to third rank by 2004-05 due to increasing mechanization of agricultural operations, the share of draft power declined from 33.02 percent in 1960-61 to 9.72 percent in 2004-05 (Fig. 5.1).

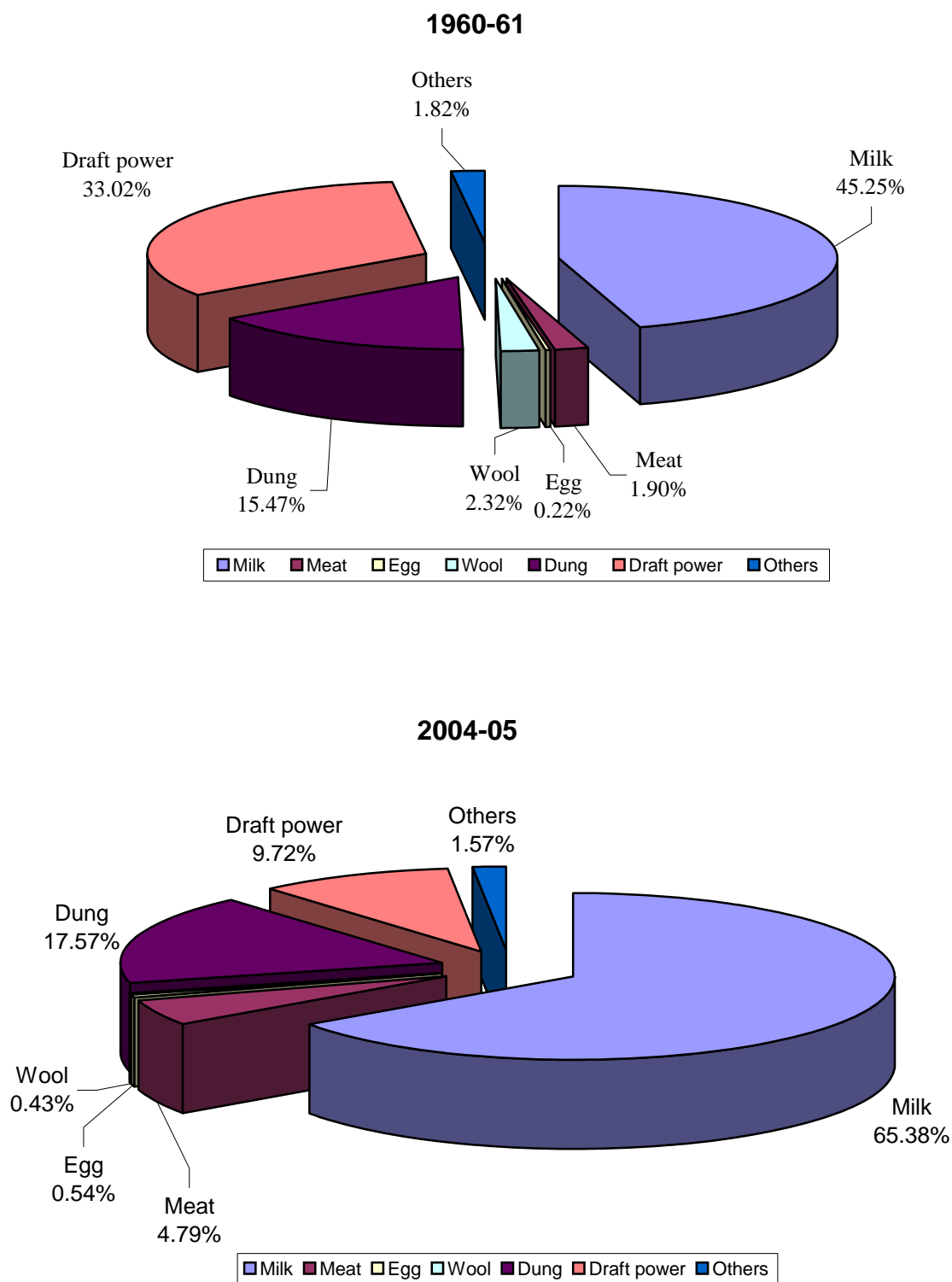
There has been a shift in the priority to the farming community from the production of work animals to that of milch animals since 1970-71. This has been reflected in the structural changes in the bovine population. It has been reported that use of animal labour in agricultural operations in Rajasthan is declining by 5.5 percent per annum (Kumar and Mruthyunjaya, 1992). As in case of dung, the share of draft power in total value of output also showed wide variations till 90's in current and constant prices.

Meat group :

The nominal value of meat group (including poultry meat) has increased 126 times, from Rs.5.18 crore in early 60's to Rs.652.41 crore in

¹ The current and constant price series of value of output from dung at all India level as published in National Accounts Statistics also substantiates the fact that price index of dung was very high during the 90's.

Fig. 5.1 Composition of Value of Output from Livestock Sector in Rajasthan (at current prices), 1960-61 and 2004-05.



first half of the current century, while the real value has increased more than 3 times, increasing from Rs.101.38 crore to Rs.315.44 crore during the corresponding period (Table 5.1). The percentage share has also nearly doubled from 1.93 to 4.79 percent (Fig. 5.1).

Wool and hairs :

The percentage share of this item has declined from 2.32 percent in 1960-61 to 0.43 percent in 2004-05 (Fig. 5.1). At current prices although there was about 11 times increase in value of wool and hair but at constant prices, there was a steep fall from Rs.72.95 crore in early 60's to Rs.57.04 crore in recent quinquennium indicating that the increase in current value has been only price oriented.

Eggs :

Eggs have a very minor share in the livestock output in Rajasthan. Though the percentage share of eggs in total value of output continued to be less than one percent, in absolute terms its value increased 134-fold and 15-fold in current and real terms, respectively.

Other products :

Other products include value of silkworm cocoons and honey, and value of increment in stock. The nominal value of other products between 1960-61 to 2004-05 increased 142 times; while in real term it has increased by 10 times during the period. The relative share fluctuated over time. Although from 1960-61 to 2004-05 it declined marginally from 1.82 to 1.52 percent (Fig. 5.1), the quinquennium average showed the increase in share of this item (Table 5.1). These changes in value of other products predominantly causes from changes in value of increased in stock as silkworm coon and honey has negligible presence in Rajasthan.

5.1.1.2 Growth

The total value of output from livestock sector in Rajasthan increased from Rs.268.74 crore during early 60's to Rs.14185.08 crore in the beginning of current decade registering a compound growth rate of above 11 percent at current prices (Table 5.2). In real terms, however, the growth was only about 2 percent during 1960-61 to 2004-05. The various components of livestock, registered positive and close to 2 percent or higher growth rate except wool and hair, and draft power. In case of wool and hair growth was observed negative while draft power almost stagnated during the period concerned.

The decadal growth rates bring out several interesting features. During 60's, the increase in value of output took place only because of rising prices, while the output decreased during the period. This is reflected by nearly 6 percent annual growth rate in value of output at current prices but negative growth (-1.05%) at constant prices during this period. In 60's, the decrease in real output of livestock sector occurred largely due to decline in the major constituents, i.e., milk group.

Thereafter, the value of output increased substantially, both, at current and constant prices. The increase was particularly notable during the period 1990-91 to 2004-05. Since 1990-91, the nominal output has grown at the rate of 12.29 percent per annum while real output has increased by 4.95 percent per annum. The milk group has registered spectacular performance after 90's registering a compound annual growth rate of 5.26 percent. The efforts of the government, particularly the departments concerned with dairying, animal husbandry and veterinary services have played a role in raising the productivity of our national milch herd (Kurien, 1997). The contribution of the cooperative sector has also been of great importance, both in creating a market and in supporting farmers with technical inputs, viz., feed, breeding and veterinary services. These technical inputs, made available under programmes like Operation Flood, provided an impetus for the higher growth of this sector.

Among the other components of livestock output, although the absolute value of meat group continued to be low the growth rate is increasing continuously. It has increased from almost negligible growth in the decade of 60's to 5.02 percent in the period of 1990-91 to 2004-05. Eggs also have negligible value but due to low base, the growth rate was very high in this item (7.44%) during the entire period and over 6 percent during different decades. The value of output of wool and hair has reported negative growth up to 1990's and has only pick up after 90's to around 2 percent per annum. As stated earlier, higher prices during 1990's lead to quantum jump in growth rate of dung from about 1.3 percent in 70's and 80's to over 5.5 percent after 90's. The growth rate in animal draft power was either negative or stagnated over the decades. The rate of decline was higher during the input intensification era (1980's). The declining trend of animal draft power further substantiated the fact of mechanization of agriculture in the state. The compound annual growth rate in value of other products has declined from 3.77 percent per annum in the decade of 1970's to -3.88 percent during the period 1990-91 to 2004-05. As stated earlier the decline in growth rate was due to decline in population stock.

5.1.2 Value of Input of Livestock : Composition and Growth

Having examined the growth trends in value of output, we now look into the growth trends in value of inputs. The input value included values of feed (green fodder, dry fodder and concentrates), labour and interest on value of livestock population. The nominal value of total input has increased from Rs.360.33 crore during the early 60's to Rs.9731.8 crore in the beginning of this century (Table 5.3) registering an annual compound growth rate of 8.72 percent (Table 5.4). In real terms the growth was only 2 percent per annum.

Livestock feed :

Over the last 45 years, the share of feed and fodder ranked the highest in total value of inputs. But the share has declined from 71.65 percent in early 60's to around 53 percent during the first quinquennium ending 2004-05 of current century at current prices.

Table 5.3 Value of inputs for livestock production and its percentage composition in Rajasthan (Quinquennial average).

(Value in Lakh Rs.)

Items/ Periods	1960-61 to 1964-65	1965-66 to 1969-70	1970-71 to 1774-75	1975-76 to 1979-80	1980-81 to 1984-85	1985-86 to 1989-90	1990-91 to 1994-95	1995-95 to 1999-00	2000-01 to 2004-05
At Current Prices									
Feed	25856 (71.65)	37787 (75.26)	59855 (76.13)	84845 (73.68)	118773 (70.98)	197791 (70.31)	273861 (69.41)	439114 (64.22)	515730 (52.99)
Labour	3010 (8.34)	3119 (6.21)	8932 (11.35)	15337 (13.32)	24154 (14.61)	444112 (15.79)	72706 (18.43)	173081 (25.31)	361511 (37.15)
Population Stock	7223 (20.01)	9301 (18.53)	9835 (12.52)	14967 (13.00)	24177 (14.41)	39126 (13.92)	47986 (12.16)	71526 (10.47)	95939 (9.86)
Total inputs	36088 (100)	50208 (100)	78623 (100)	115148 (100)	167344 (100)	281329 (100)	394554 (100)	683721 (100)	973180 (100)
At 1993-94 Prices									
Feed	168568 (62.65)	146666 (62.21)	176585 (67.08)	188631 (66.67)	198702 (65.78)	189868 (63.68)	268441 (68.32)	373643 (70.63)	336301 (62.71)
Labour	56882 (21.14)	43856 (18.60)	40876 (15.52)	46243 (16.35)	53067 (17.57)	61301 (20.56)	73632 (18.74)	100350 (18.97)	146436 (27.30)
Population Stock	43599 (16.21)	45236 (19.19)	45798 (17.40)	48046 (16.98)	50287 (16.65)	46993 (15.76)	50836 (12.94)	55031 (10.40)	53577 (9.99)
Total	269049 (100)	235758 (100)	263259 (100)	282920 (100)	302056 (100)	298162 (100)	392309 (100)	529024 (100)	536315 (100)

Figures in parentheses are percentages of total value of input

Table 5.4 Growth trends of value of inputs and its components in Rajasthan at current and 1993-94 prices.

Item/Period	1960-61 to 1970-71	1970-71 to 1980-81	1980-81 to 1990-91	1990-91 to 2004-05	1960-61 to 2004-05
At Current Prices					
Feed	8.32	7.23	9.29	6.49	8.00
Labour	4.81	11.10	11.58	17.26	12.85
Population Stock	5.84	9.39	7.79	7.22	7.21
Total inputs	7.60	7.99	9.43	9.42	8.72
At 1993-94 Prices					
Feed	-0.76	0.60	0.94	1.98	2.07
Labour	-4.72	2.47	2.94	7.06	2.60
Population Stock	0.64	0.99	-0.79	0.54	0.53
Total inputs	-1.29	0.94	1.05	3.12	1.99

At constant prices, value of feed input has increased at the compound annual growth rate of 2.07 percent during the whole period and it has improved from negative in 60's to around 2 percent after 90's.

At constant prices, the share of feed and fodder fluctuated and came down in 60's, late 80's and during the beginning of current decade. This was because of regular drought in mid 60's, severe drought of 1987 and 2003, respectively. According to a study, with current practices the fodder deficit in Western Rajasthan during normal year is estimated to be as high as 60 percent of demand while during drought years the deficit might range from 76 percent in western districts to 82 percent in eastern regions (Narain and Rajore, 2006).

The composition of livestock feed has also changed over time. In first quinquennial, i.e., 1960-61 to 1964-65, dry fodder accounted for around 61 percent of the total livestock feed. This came down to 41 percent in last quinquennial (Appendix-VII). The share of fodder (green + dry) declined from 95 to 75 percent during the corresponding period. The share of green fodder in total feed increased from around 35 percent in early 60's to 49 percent in beginning of 1980's and then again declined to 30 percent in last

quinquennial. The declining share of green fodder in later period was probably due to the adoption of stall feeding and shrinking of area under paramount pasture and grazing land and forest cover. The continuously increasing share (from 5% to 25%) of concentrates is the good sign of livestock development in the state.

Labour :

During the overall period (1960-61 to 2004-05), the nominal value has increased at the significantly high annual growth rate (around 13%) increasing from Rs.30 crore to Rs.3615 crore, while the real value has increased at relatively low growth from around Rs.569 crore to Rs.1464 crore during the period. At current prices, the percentage share of labour in total input value has increased continuously from 8.34 percent in early 60's to more than 37 percent in last quinquennial (2000-01 to 2004-05), it fluctuated from 15.53 to 27.30 percent at constant prices (Table 5.3).

The declining share of labour up to early 70's is because of decline in the number of work force in agriculture during the census (1961 and 1971), while in 1990's it is because of increased share of livestock feed. Value of labour has maintained an upward trend in state at current and constant prices from significantly negative growth (-4.72) in 1960's to high positive growth (7.06%) in last period. The higher growth of labour particularly during the last period (1990-91 to 2004-05) seems to be due to substitution of labour from agriculture to livestock and better marketing infrastructural facilities rendering livestock as commercial.

Interest on population stock :

The relative factor share of interest on population stock has continuously declined over the period (Table 5.3). It has declined from around 20 percent in early 60's to merely 10 percent in the quinquennium ending current decade at current prices. Almost similar pattern was found in terms of real value of this item. In fact, the decline in the share of interest component in total input value is offset by increase in the value share of labour, while growth rate almost stagnated at less than 1 percent (Table 5.4).

5.1.3 Output, Input and TFP Indices

It emerged from the discussion in the preceding section that over the period of time, there has been an increase in the value of output and inputs in the state. However, increasingly, the expansion in value has come largely through the rise in prices.

After having discussed the growth trends for output and inputs individually, now come to see the simultaneous changes in total output in response to changes in total inputs in the form of indices. The results of output, input and TFP indices computed by using Tornqvist-Theil index and its growth over different time span are presented in Table 5.5, Figure 5.2 and Appendix-VIII and discussed as under :

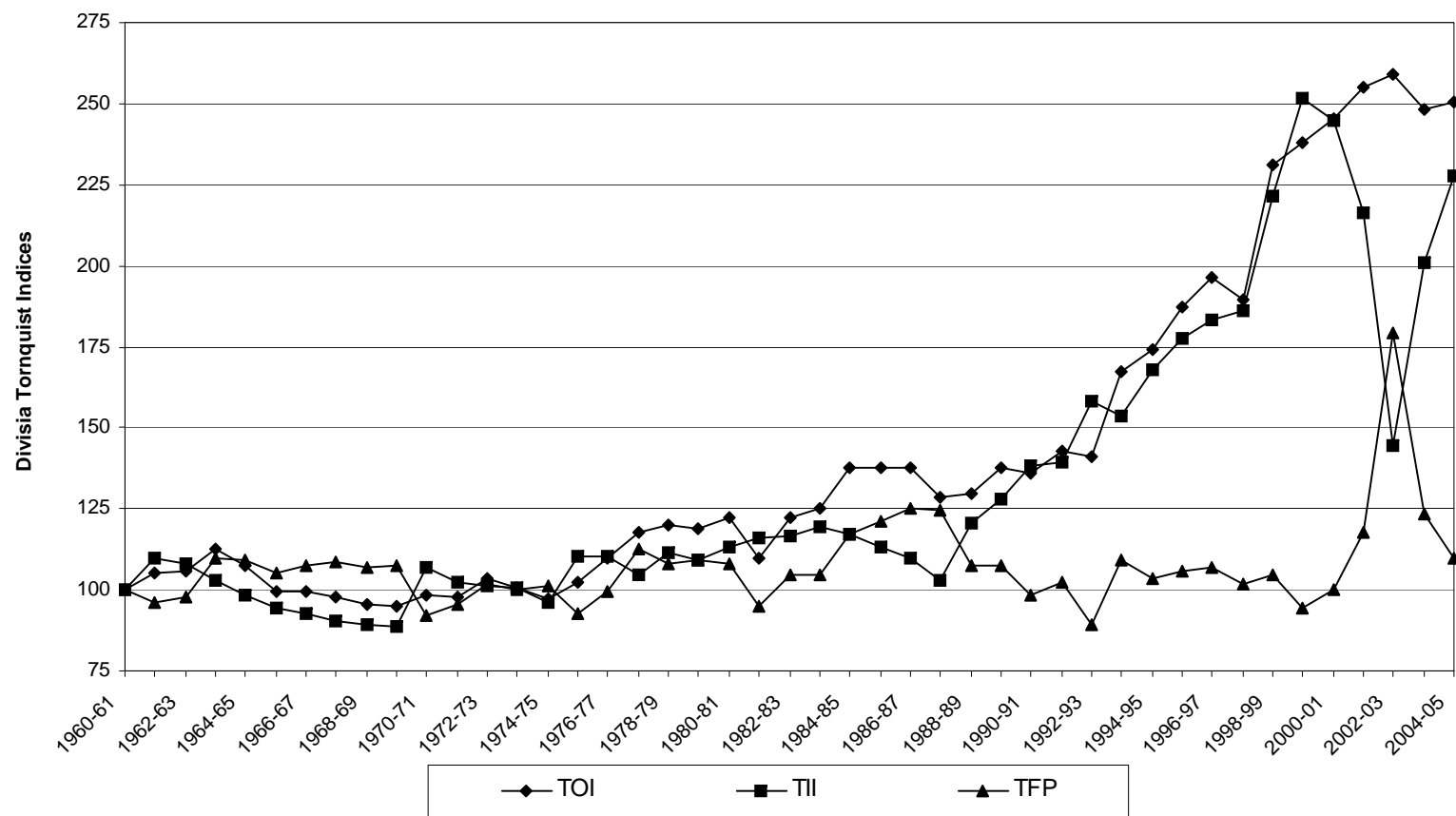
Current prices : The output index at current prices rose from 100 in base period 1960-61 (=100) to 186.6 in 1970-71 (compound annual growth rate 5.8%). In the subsequent decade, the increase was very sharp at compound annual growth rate of 11.7 percent. The rate of increase came down in 1980's to 9.75 percent and again jumped to 12.43 percent after 1990's (Table 5.5). Overall the output index increased to 7058.9 in 2004-05 (Appendix-VIII) and registered a compound around growth rate of 10.93 percent.

Table 5.5 Compound annual growth rate of output, input and TFP indices in Rajasthan at current and 1993-94 prices.

(in percent)

Item / Period	Compound Annual Growth Rate of					
	Output Index		Input Index		TFP Index	
	At Current Prices	At 1993-94 prices	At Current Prices	At 1993-94 prices	At Current Prices	At 1993-94 prices
1960-61 to 1970-71	5.80	-1.05	7.61	-1.29	-1.81	0.24
1970-71 to 1980-81	11.71	2.53	7.99	0.94	3.72	1.59
1980-81 to 1990-91	9.75	1.50	9.43	1.05	0.32	0.45
1990-91 to 2004-05	12.43	5.12	9.17	3.13	3.26	1.99
1960-61 to 2004-05	10.93	2.26	8.72	1.99	2.21	0.27

Fig. 5.2 Trends in input, output & TFP indices in Rajasthan's livestock sector at 1993-94 prices (1960-61 to 2004-2005)



The TFP index declined during the 60's because of higher growth in input index (7.61%) as compared to the growth in output index. The TFP picked up to 102.4 in 1979-80 from 75.6 in 1970-71 and reported compound annual growth rate of 3.72 percent during the period. This may be attributed to operation flood programme during 1970's. But this could not be sustained during the subsequent decades and declined to almost negligible (0.32%) growth during 80's. Table 5.5 and Appendix-VIII shows that after 1990's again TFP has increased to 3.26 percent and explained approximately 26 percent of the growth in aggregate output; factor accumulation contributed the remainder to output growth. Overall TFP has increased at the compound annual growth rate of 2.21 percent during 1960-61 to 2004-05.

Constant prices : In real terms, output index increased at the annual compound growth rate of 2.26 percent, which is marginally more than the input index (1.99%) during 1960-61 to 2004-05. Thus, the TFP growth rate was low (0.27%) indicating that the overall sustainability of livestock sector is not very encouraging. The technology was only responsible for about 12 percent increase in output growth. The input oriented growth could not be sustained if further improvement does not occur. Both, the output and input indices fluctuated over the period (Fig. 5.2) but the fluctuations were more in input index than output index. During the period of droughts, the input index came down but output index did not decline much. For instance during 2002-03 the input index dropped to 145 from 216 in 2001-02, but the output index increased to 259 from 255 during the corresponding period (Fig. 5.2). This phenomena show that the livestock is a coping mechanism for drought management in the state and improve the sustainability of agriculture. This was particularly true during 80's and 90's with the development of livestock infrastructure facilities in the state. During the decade of 60's, both the output and input indices declined but the rate of decline was more in case of input indices (-1.29%) as compared to output indices (-1.05%) and thereby TFP was positive but was very low at the rate of 0.24 percent. Although the period was slightly different but the similar results were found by Kumar and Pandey

(1999) at all-India level during the period 1950-51 to 1970-71. TFP increased to 1.59 percent during 1970's and contributed about 63 percent to the 2.53 percent growth rate in output indices.

During the 1980's, it declined to 0.45 percent and again jumped to around 2 percent during the period 1990-91 to 2004-05 and explained the 38 percent of the output growth rate. But the TFP growth rate, calculated based on excluding the index of severe drought year, i.e., 2002-03 was only 1.06 percent during the period.

It emerged from the discussion that the output growth rate did not decline much during the drought period indicating that the livestock was the coping mechanism during the year of drought. Although, the TFP was positive during the study period, but was very low indicating that the overall sustainability status was not encouraging in the state. The output growth was largely input driven which would not sustain if further technological improvement did not take place. There were wide decadal variations and the real upswing was started after 1990's. This momentum need to be maintained to improve the sustainability of livestock sector in the state.

5.2 SUSTAINABILITY INDEX OF LIVESTOCK PRODUCTION : ZONAL AND DISTRICT LEVEL

Having examined the sustainability of livestock production system following TFP approach at state level, we now move to carryout an in-depth analysis of relative sustainability status of livestock production at the agro-climatic and district level. The relative sustainability status is a pre-requisite for identifying the strongly and weakly linked aspects of sustainable development of livestock for a particular area. It is also instrumental in prioritizing policy attention and orientation of programmes towards sustainable development of a region. Based on these considerations, the Sustainable Livestock Production Index (SLPI) was constructed for 7 agro-climatic and all 32 districts using the latest triennial average data of the relevant indicators as detailed in the methodology. In the first section, we discuss the relative sustainability status of various agro-climatic zones, while in second section the same is discussed in detail at district level.

5.2.1 Livestock Sustainability Status : Agro-Climatic Zones

SLPI is a simple average index of three important dimensions, viz., Economic Efficiency Index (EEI), Social Equity Index (SEI) and Ecological Security Index (ESI) that are in turn based on 8 indicators. SLPI* is weighted average index of above mentioned three indices, in which weights assigned to each component was calculated as the ratio of its inverse contribution to the sum of all the three inverse proportions as mentioned in the methodology section. Table 5.6 presents the value of indices and relative ranking of agro-climatic zones based thereupon. The mean value of SLPI 0.39, much lower than the maximum obtainable value of 1.00, indicating that in general, the sustainability status of livestock production is low in Rajasthan. This substantiates our earlier findings discussed in the previous section about somewhat weak sustainability of livestock production system. In case of agriculture also, Saleth (1993) reported the similar findings and she observed that the average Sustainable Livelihood Security Index (SLSI) score across agro-climatic zones in Rajasthan is 0.389.

The inter-zonal variations in SLPI are not very sharp (C.V. = 21.6%). The irrigated north-western plain zone is the top ranking zone with SLPI of 0.55. This zone comprises the agriculturally advanced districts of Ganganagar and Hanumangarh. These districts have alluvial soil deposits of Ghaggar river being loam to silty loam in texture. Due to the availability of three canal systems, proportions of land available for cultivation is high which facilitates livestock production in the zone. The semi-arid eastern plain (SLPI = 0.454) and flood prone eastern plains (SLPI = 0.397) rank second and third, respectively with SLPI greater than state average. The worst performing zones are southern and south-eastern plains and southern plains and Aravali hills. The districts of these zones are either with hilly topography such as Udaipur, Chittorgarh, Dungarpur or with low area under cultivation and irrigation such as Rajsamand and Dungarpur. Largely the cash crops like cotton and sugarcane and horticultural crops are grown in these areas. The livestock production is poor in these zones because of low population and low productivity of milch animals.

Table 5.6 Relative sustainability status of livestock production : across agro-climatic zones of Rajasthan.

	Agro-climatic zones	EEI	Rank	SEI	Rank	ESI	Rank	SLPI	Rank	SLPI*	Rank
1.	Irrigated north western plain (Zone-I)	0.780	1	0.554	1	0.314	3	0.550	1	0.479	1
2.	Semi-arid eastern plain (Zone-II)	0.706	2	0.474	3	0.182	7	0.454	2	0.333	5
3.	Flood prone eastern plain (Zone-III)	0.507	3	0.468	4	0.216	6	0.397	3	0.343	3
4.	Southern plain & Aravali hills (Zone-IV)	0.222	6	0.475	2	0.318	2	0.338	6	0.307	6
5.	Arid western plain (Zone-V)	0.378	5	0.354	7	0.323	1	0.352	5	0.351	2
6.	Transitional plain (Zone-VI)	0.472	4	0.440	5	0.226	5	0.380	4	0.340	4
7.	Southern and south-eastern plain (Zone-VII)	0.158	7	0.430	6	0.286	4	0.292	7	0.247	7
	Mean	0.461		0.457		0.267		0.395		0.343	
	C.V. (%)	50.1		13.2		21.6		21.6		20.3	

EEI = Economic efficiency index; SEI = Social equity index and ESI = Ecological security index.

On the basis of the weighted index, viz., SLPI* the values of the indices are lower than estimated SLPI and also there is some changes in the relative ranking of the zones. For instance, the semi-arid eastern plain that ranked second as per the SLPI slipped to fifth rank based on SLPI*. Considering the SLPI* ranking, it is one of the bottom three zones that should be the priority focus of development programmes. Categorizing the zones into three categories² based on SLPI* : < 0.3 (low), 0.3 to 0.5 (medium) and >0.5 (high) sustainable, the southern and south-eastern plain zone performed low. While remaining six zones performed moderately in the sustainability, none of the zone scored in the category of high sustainability (Fig. 5.3).

The results indicate that ranking of regions differ slightly from their ranking based on SLPI*. The downward movement of SLPI* values are due to the effect of the weighting procedure that deflects the better performance slightly but inflates the poor performance substantially. Such an equalizing effect is favourable for regions with poor performance as inter-regional priority for investment allocation will be inverse to their component ranking.

The scores of SLPI and SLPI* are only the summary picture of relative sustainability condition of each agro-climatic zone. It is interesting to dig deeper into each zone's performance in all 3 dimensions (Table 5.6). The results show that there are wide inter-zonal variations in the status of economic sustainability as captured through EEI. The index ranges from a low of 0.158 in southern and south-eastern plain to 0.780 in irrigated north western plain with coefficient of variation as high as of 50 percent. The agro-climatic zones advanced in livestock as well as agricultural production, viz., irrigated north western plain, semi arid eastern plain and flood prone eastern prone were the top three agro-climatic zones in economic efficiency (EEI>0.5); whereas the southern and southern plain, and southern plain and Aravali hills were in the bottom of the ranking of EEI. The remaining two agro-climatic zones, viz., arid western plain and transitional plain performed moderately in economic efficiency (0.3-0.5). The rank correlation coefficient

² The categories are made based on the earlier literature like Saleth (1993), Sen and Hatai (2007) and based on the range of index.

Fig. 5.3 Sustainability scenario of livestock production in Rajasthan based on SLPI*.



Agro-climatic Zones



Districts

among the SLPI* and in their three aspects, viz., economic, social and environmental was calculated using Spearman's rank correlations and presented in Table 5.7. The zones with poor performance in economic aspect were also poor in overall sustainability (SLPI*).

Table 5.7 Rank correlation coefficient among SLPI* and its dimensions in different agro-climatic zones.

Districts	Economic Efficiency Index	Social Equity Index	Ecological Security Index	SLPI*
Economic efficiency index	1.000	0.571	-0.429	0.679
Social equity index		1.000	-0.143	0.143
Ecological security index			1.000	0.214
SLPI*				1.000

The Social Equity Index (SEI) scores for all the agro-climatic zones when compared, shows that agro-climatic zones have moderate scores ranging from 0.354 in arid western plains zone to 0.554 in irrigated north-western plains. The inter-zonal variations are quite low suggesting nearly uniform situation of the state in terms of social indicators considered in this study. There was positive rank correlation (0.571) between the ranking of economic efficiency and social equity index (Table 5.7).

Unlike the SEI, Ecological Security Index (ESI) scores were at the low level, ranging from 0.182 to 0.323, but the inter-zonal variation was relatively higher (C.V. 21.6%) than SEI (C.V. 13.2%) and relatively lower than EEI. Results show that out of seven agro-climatic zones, four zones were having ESI score less than 0.3. Among the low ESI zones, three were from eastern and south eastern part of the state, while one was transitional plain zone. The regions with relatively better ecological security were arid western plain, southern plain Aravali hills and flood prone eastern plain. These regions, in general, whether have large area under forest and grazing lands (mountain regions) or have low livestock population density.

Thus, it emerges that ecological dimension is the weakest aspect of overall sustainability status of all the zones, while the economic dimension is the strongest (except the bottom two ranking zones).

From the policy perspective, regional prioritization of investment in livestock, although all the zones need attention, but the agro-climatic zone with SLPI* of less than 0.3, viz., southern and south-eastern plain zone should receive top priority.

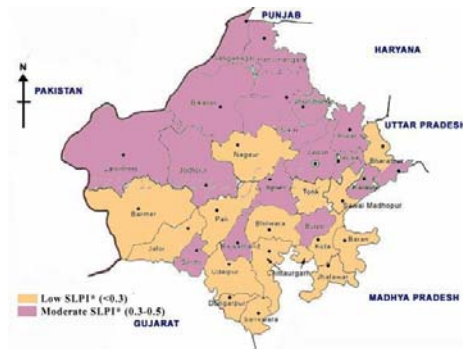
Given the inter-regional investment allocation, the SLPI* approach could also provide further policy guidance as to the specific programmes and projects based on the relative values of EEI, SEI and ESI. For instance, the southern and south-eastern plain, and southern plain and Aravali hills require policy attention on economic aspect, while in case of southern and south-eastern plain zone programme should be focused on ecological dimension.

5.2.2 Livestock Sustainability Status : Districts

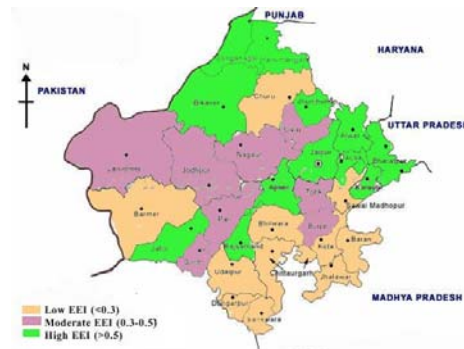
The sustainability status discussed in preceding section at agro-climatic zone level is only the summary picture of the livestock sustainability status in corresponding zone. To gain insight into district-wise performance of various indicators for appropriate district planning exercise was also carried out at district level and the results are presented in this section.

Table 5.8 presents the indices of sustainable livestock and its three dimensions, viz., economic, social and ecological sustainability and Figure 5.4 gives a cartographic representation of SLPI* based on the categorization mentioned earlier as low (<0.3), medium (0.3-0.5) and high (>0.5). Table 5.8 shows that the value of overall sustainability measured in terms of SLPI*, at the district level ranged from a low level of score (0.114) in Dungarpur district to a moderate level of 0.495 in Hanumangarh district, i.e., none of the 32 districts crossed the SLPI* value 0.5. Almost half of 32 districts were low in their sustainability status, while remaining half were performed moderately (Fig. 5.4), and no district fell in high category as stated earlier.

Fig. 5.4 Classification of districts according to sustainability status.



a) Overall sustainability status (SLPI*)



b) Economic sustainability status (EEI)



c) Social sustainability status (SEI)



d) Ecological sustainability status (ESI)

Table 5.8 Relative sustainability status of livestock production : across various districts of Rajasthan.

Districts	EEI	Rank	SEI	Rank	ESI	Rank	SLPI	Rank	SLPI*	Rank
Ajmer	0.732	4	0.537	9	0.191	26	0.487	9	0.354	11
Alwar	0.657	6	0.669	3	0.145	31	0.490	8	0.302	17
Banswara	0.139	28	0.386	24	0.218	21	0.248	31	0.209	31
Baran	0.133	29	0.412	21	0.364	6	0.303	26	0.237	29
Barmer	0.292	22	0.368	26	0.237	17	0.299	27	0.290	19
Bharatpur	0.611	8	0.589	6	0.142	32	0.447	12	0.288	21
Bhilwara	0.281	23	0.416	19	0.228	18	0.308	24	0.289	20
Bikaner	0.562	11	0.392	23	0.524	1	0.493	7	0.481	3
Bundi	0.341	20	0.396	22	0.321	10	0.353	17	0.350	12
Chittor garh	0.124	31	0.480	14	0.261	14	0.288	30	0.214	30
Churu	0.262	24	0.467	16	0.353	7	0.361	16	0.341	13
Dausa	0.803	3	0.518	11	0.206	22	0.509	4	0.374	8
Dholpur	0.533	13	0.547	7	0.225	19	0.435	13	0.368	9
Dungarpur	0.047	32	0.546	8	0.299	11	0.298	28	0.114	32
Ganganagar	0.864	1	0.514	12	0.293	12	0.557	1	0.460	4
Hanumangarh	0.705	5	0.597	5	0.337	9	0.546	3	0.495	1
Jaipur	0.858	2	0.633	4	0.154	30	0.548	2	0.324	14
Jaisalmer	0.379	19	0.239	31	0.390	5	0.336	21	0.320	15
Jalore	0.610	9	0.253	30	0.171	29	0.345	18	0.262	26
Jhalawar	0.244	26	0.416	18	0.255	15	0.305	25	0.287	23
Jhunjhunu	0.595	10	0.708	2	0.220	20	0.508	5	0.393	7
Jodhpur	0.476	17	0.347	28	0.206	23	0.343	19	0.305	16
Karauli	0.617	7	0.487	13	0.411	4	0.505	6	0.491	2
Kota	0.215	27	0.442	17	0.285	13	0.314	23	0.288	22
Nagaur	0.319	21	0.374	25	0.195	25	0.296	29	0.274	24
Pali	0.490	16	0.352	27	0.187	27	0.343	20	0.293	18
Rajsamand	0.535	12	0.534	10	0.343	8	0.471	11	0.451	5
Sawai Madhopur	0.255	25	0.215	32	0.249	16	0.240	32	0.238	28
Sikar	0.498	14	0.746	1	0.197	24	0.480	10	0.357	10
Sirohi	0.393	18	0.415	20	0.489	3	0.432	14	0.429	6
Tonk	0.493	15	0.289	29	0.181	28	0.321	22	0.272	25
Udaipur	0.131	30	0.478	15	0.500	2	0.369	15	0.255	27

For a comprehensive analysis of various dimensions, the discussion is carried out according to categorization of districts in low and medium sustainable categories.

5.2.2.1 Low SLPI* (<0.3) districts

The visual presentation of district indices in Figure 5.3 show that the districts with poor sustainability status are mostly located in southern and south-eastern part, falling under the zones south and south-eastern plain, southern plain and Aravali hills, and transitional plain.

More interestingly, all the districts of moderately performing zones did not perform consistently. For instance, Barmer of arid western plain, Bharatpur and Swai Madhopur of flood prone eastern plain and Tonk of semi-arid eastern plain exhibited changing purposes (Fig. 5.4).

Among the low SLPI* districts, the performance of Swai Madhopur district is of particular concern. The district performed poorly in all the three dimensions, viz., economic, social and ecological. The indices of each of these three dimensions were <0.3 in the district. In none of the other districts with overall low SLPI*, the performance has been consistently poor across all dimensions, as in Swai Madhopur. The districts of Dungarpur, Banswara, Chittorgarh, Jhalawar, Kota, Bhilwara and Barmer have EEI and ESI indices <0.3, while for Jalore and Tonk, it is the social and ecological aspects these were weak (SEI and ESI <0.3). A few districts like, Baran and Udaipur showed overall low SLPI* index largely due to poor economic sustainability and in terms of social sustainability; Nagaur, Bharatpur and Pali were poor (Fig. 5.4).

The rank correlation coefficient between the EEI and SLPI* of these 15 districts was 0.661, indicating that the districts with poor economic sustainability also performed worstly in overall sustainability (Appendix-IXb). On the contrary, the rank correlation coefficient was found significantly negative (-0.90) between the economic and ecological sustainability of the low SLPI* districts.

5.2.2.2 Moderate SLPI* (0.3 to 0.5) districts

As stated earlier, over half of the districts were having SLPI* of moderate order and were situated in north and north-western part of the state (Fig. 5.4). Hanumangarh, Karauli, Bikaner, Ganganagar and Rajsamand districts occupied on the top five rankings; while Alwar, Jodhpur, Jaisalmer, Jaipur and Churu bottom five rankings among the moderately performed districts (Table 5.8).

Except Churu in economic aspect and Jaisalmer in social aspect, all these districts performed in the moderate range of (0.3 to 0.5) or high range (≥ 0.5) in these two dimensions. The rank correlation coefficient was also positive (Appendix-IXc), but not statistically significant between the EEI and SLPI*, and SEI and SLPI*. Though, the moderate SLPI* districts were low or moderate in ecological security index except Bikaner (Fig. 5.4) which performed high, the rank correlation coefficient among ESI and SLPI* was significantly high at 0.556.

Indicator-wise performance of these districts, is somewhat more revealing. The detailed table showing the value of each index of the 8 indicators is presented in Appendix-X. The results show that all the best performing districts did not perform consistently across all the 8 indicators and the poor sustainability districts were also better in some of their indicators. For example, Hanumangarh topped in overall sustainability, but it was lowest in the indicator, ratio of pasture and grazing land to net sown area (NSA) and performed low in the indicator, livestock infrastructure facilities than many other districts. As against this, Dungarpur and Chittorgarh did poorly in all the indicators of economic and ecological sustainability, but both the districts scored well in growth rate of CPRs, and Dungarpur alone scored high in livestock infrastructural facilities.

The rank correlation between livestock productivity and two other indicators of economic sustainability, viz., labour productivity and calories availability was positive and significant (0.591 and 0.70, respectively). This

indicates that in general, improving the productivity of livestock would also enhance labour productivity and availability of calories. Interestingly, female literacy and livestock productivity also had high rank correlation (0.577) pointing towards positively linkages between the education of female and production performance of livestock. On the other hand, the negative rank correlation between the indicators of economic sustainability and proportion of area under pasture and grazing land probably due to existence of poor condition of CPRs and hence its negligible role in livestock productivity.

Thus, the indices of these indicators are more important for the policy guidance to specific programmes and projects. In terms of results presented in Appendix-Xa, although most of the districts require attention in all dimensions but the bottom five ranking districts require most immediate attention.

The southern and south-eastern districts of Dungarpur, Udaipur, Chittorgarh, Banswara, Baran and Kota with Churu and Jaisalmer districts of western region were poorest in the indicators of livestock productivity (Dungarpur, Jaisalmer, Udaipur, Chittorgarh and Banswara), labour productivity (Churu, Dungarpur, Chittorgarh, Banswara and Baran) and calories availability (Kota, Dungarpur, Udaipur, Baran and Banaswara). Therefore, programmes should be focused on improving the productivity of livestock by providing the technologies of crossbreeding, better feed and fodder, and mineral mixture facilities in these districts.

The districts of Jalore, Banswara, Dungarpur, Jaisalmer and Tonk were the bottom five ranking districts in the indicator, female literacy rate of social dimension and therefore, programmes should be directed to improve the literacy rate among women. The priority of livestock infrastructural facilities should be channelized in the entire arid western plain zone consisting the districts of Jaisalmer, Barmer, Bikaner, Jodhpur and Churu. While in the

districts of Kota, Swai Madhopur, Tonk, Dausa and Jaipur common property resources are shrinking and hence, immediate focus should be on conservation of these resources.

In the districts of Udaipur, Banswara, Jaipur, Alwar and Chittorgarh, the livestock population is vastly surplus in relation to feed and fodder availability in the districts. Therefore, most immediate policy direction required is to increase the availability of feed and fodder and to decrease the population of unproductive animals in these districts. In the districts of Hanumangarh, Churu, Nagaur, Ganganagar and Bharatpur, emphasis is required on conservation of pasture and grazing lands.

5.3 SUSTAINABILITY OF DAIRY FARMING : HOUSEHOLD LEVEL

In the preceding sections, an attempt was made to measure the sustainability of livestock production at macro level in Rajasthan. The major share of income from animal husbandry sector in the state comes from dairy farming. It provides jobs to millions and supplements the income of the rural masses in general, for their subsistence. Therefore, it is very important to examine the sustainability at household level. In this section, the sustainability at households was calculated by aggregating the three dimensions, viz., economic, social and ecological for each household. The economic sustainability is reflected through cost of milk production and productivity of inputs, namely, labour, capital and feed; while the social sustainability is examined by taking the variables, family labour income as a percentage of MPCE, women empowerment index and drudgery of work involved in physical work. Indicators for ecological sustainability were : the ratio of use of dung for fuel to manure, enteric methane emissions and index of breeding practices followed by the farmers. All these aspects of sustainability were weighted in overall Sustainable Dairy Farming Index (SDFI), i.e., into an overall figure that indicates farm sustainability.

This section is divided into five subsections. The first subsection describes the socio-economic profile of sample households. The second subsection gives economic dimension of sustainability, while in third and fourth, social and ecological aspects are presented, respectively. The overall sustainability of dairy farming is described in last subsection.

5.3.1 Socio-Economic Profile of Sample Households

This section provides general information about the socio-economic profile of the sample households delineating their family composition, literacy status, occupational pattern, resource position, etc. for the comprehensive understanding of sustainability of dairy farming at micro-level. The present study at household level covered 120 households from four villages spread over four tehsils. The selected villages were Raisingih Ka Bass of Chomu tehsil, Jaichandpura from Jamwaramgarh tehsil, Nathi Ka Bass from Phulera thesil and Dudhawala from Bassi tehsil.

5.3.1.1 Family size and composition

Animal husbandry is basically a labour intensive activity in rural India. Mostly, family labour is engaged in this enterprise. Therefore, the family size and its composition has been documented at the foremost and presented in Table 5.9. From the table it can be observed that there was prevalence of large family in the study area with family size of about 9 persons. The average family size increased with the herd size category suggesting that larger families maintained more milch animals perhaps due to their greater milk requirement and / or higher availability of family labour facilitated rearing of more milch animals. On households with small herd size category (1-2 animals) the average size of family was about 7, it increased to nearly 9 on medium herd size (2-4 animals) households and further to 12 on the households rearing more than 4 animals, that is large herd size category.

The sex ratio among the sample households as expected was in favour of males. However, the number of females per 1000 males was only 800 as against the state average of 922 and district (Jaipur) average of 897.

Table 5.9 Average family size of sample households in Jaipur.

Category	Adult			Children			Average Family Size		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Small	2	2	4	2	1	3	4	3	7
Medium	3	2	5	2	2	4	5	4	9
Large	4	3	7	3	2	5	8	5	12
Overall	3	2	5	2	2	4	5	4	9

Figures are rounded off to zero decimal point.

5.3.1.2 Literacy

Literacy is the basic instrument for improving the quality of human resources. The awareness and knowledge level of the farmers is best reflected through their literacy status and educational attainment.

In the study area, the literacy level of adult males was higher than the all-India average of 64.8 percent. However, the gender disparities in literacy status were very striking as only 34 percent adult females were literate as against 76.6 percent adult males.

The literacy level in males was higher but their educational attainment was low. Most of the adult males had received education up to primary level. Similarly, the literate females also had poor educational status confined up to primary schooling.

5.3.1.3 Operational holding

Land is one of the most important scarce factors of production. Often, it has been observed that in areas where size of land holding is small, dairy farmers constrained by poor access to land are unable to cultivate green fodder for dairy animals. Among the sample households, farmers with larger size of land holding could maintain more animals as is evident from direct relationship between size of operational holding and herd size category.

The average size of operational holding was 2.35 hectares, of which nearly 68 percent was irrigated. The dairy farmers maintaining small herd of animals, on an average, operated 1.39 hectares of land, about half of which

was unirrigated. The medium category farmers had more operational land (average 2.74 ha) and also better access to irrigation facilities (63.5% area under irrigation). On the larger herd size almost entire holding was irrigated (Table 5.10).

Table 5.10 Access to land resources.

(in ha)				
Type	Small	Medium	Large	Overall
Operational holding	1.39	2.74	3.90	2.35
Irrigated	0.71	1.74	3.37	1.60
Unirrigated	0.68	1.00	0.53	0.75

5.3.1.4 Occupational status

The crop cultivation was the main occupation providing major proportion of the income to the sample households while dairy farming was undertaken as subsidiary enterprise. In 3 of the sample households, dairying was providing major income. Of these two had small herd of 1-2 milch animals. A few (13) households with non-farm employment (service and business) as main occupation also reared milch animals (Table 5.11).

The socio-economic profile of sample households indicates that broadly, the dairy farmers had large family size and poor educational attainment. And, in general, the access to land and irrigation resources was much better with farmers owning larger herd size than their counterparts.

Table 5.11 Distribution of herd owners according to their main occupation.

(in Nos.)					
Categories	Agriculture	Dairy	Service	Business	Total
Small	49 (87.50)	2 (3.57)	5 (8.93)	-	56 (100.00)
Medium	33 (84.62)	-	5 (12.82)	1 (2.56)	39 (100.00)
Large	22 (88.00)	1 (4.00)	1 (4.00)	1 (4.00)	25 (100.00)
Overall	104 (86.67)	3 (2.50)	11 (9.17)	2 (1.67)	120 (100.00)

Figures in parentheses indicates percentages to total.

5.3.2 Economic Dimension

Cost of milk production is a very important indicator of economic sustainability and can help the farmers in taking important management decisions. It provides the basis for delineating the possibilities of controlling cost of milk production and improving the economic sustainability. By scaling down the costs, the dairy farmers can obtain a good margin of returns together with offering fair price to the consumer. Generally, a dairy farmer can improve the economic sustainability of dairy farming in two ways: (i) by increasing milk production, and / or (ii) by reducing cost of milk production. The former one is possible by increasing the productivity of animals, while the later one comes through better utilization of various factors of production, i.e., by improving the productivity of input factors. Thus, cost of milk production and productivity of major inputs was computed and its results are as follows :

5.3.2.1 Cost of milk production

The cost of milk production for three types of dairy animals, viz., local cow, crossbred cow and buffalo were worked out for each household. The average of the same for the households classified by the herd size categories is presented in Table 5.12, while the average maintenance cost across herd size categories is given in Appendix-XI.

The overall cost of milk production was found to be lowest for crossbred cow (Rs.9.38/lit.), followed by local cow (Rs.11.69/lit.) and buffalo (Rs.12.36/lit.). Across herd size categories, it was observed that the average cost of milk production was inversely related to the herd size category. For local cow, crossbred cow and buffalo, the cost of milk production was highest for small herd size and lowest for large herds. The inverse relation can be explained partly in terms of higher yield of animals and partly due to economies in fixed cost (excluding the cost of animal) on larger herd (Appendix-XI).

Table 5.12 Average cost of milk production.

(Rs./ Lit)

Category / Season	Overall
Local Cow	
Small	12.08
Medium	11.91
Large	10.51
Overall	11.69
Crossbred Cow	
Small	10.18
Medium	8.89
Large	8.34
Overall	9.38
Buffalo	
Small	12.75
Medium	12.09
Large	11.92
Overall	12.36

The feed cost accounted the major share in gross maintenance cost and was over 70 percent for all species and all categories of households. It was higher for crossbred cow (75.29%) followed by local cow (73.84%) and buffalo (71.04%). After the feed cost, labour cost was the second highest component and it is interesting to note that the entire labour was family labour. The expenses on labour was higher in case of buffalo (16.42%) followed by local cow (16.05%) and crossbred cow (12.90%) and decreased with the increase in size of herd except for crossbred cow in which it was highest for medium category (13.67%) and lowest on small herds (12.49%). The higher cost of labour in case of buffalo could be mainly due to the reasons that farmers in the study area were mainly concentrated on rearing of buffaloes. Again higher cost on medium category of herd was due to lower fixed cost components while the absolute cost of labour was lowest for this category. The expenses on veterinary and miscellaneous items were almost negligible for all species and across the herd size categories.

The average figures represented above, however, conceal the inter household variations in cost of milk production which varied widely across households. In case of buffaloes, such variations were maximum ranging from Rs.6.32 to Rs.32.30 per litre, followed by local cows from Rs.6.54 to Rs.28.08 per litre and crossbred cows from Rs.5.69 to Rs.13.75 per litre.

5.3.2.2 Productivity of inputs

Productivity reflects the efficiency of inputs used for producing milk. Higher productivity of inputs means the more efficient use of inputs and ensure greater returns to milk producers in dairy enterprise, thereby, improving sustainability of dairy farming. Input productivity has been computed for three inputs – labour, capital and feed inputs. The labour productivity is measured in terms of value of milk produced per manday of labour employed in dairy, while capital productivity is examined in terms of rate of returns on assets employed in dairy sector and feed productivity by milk produced (litres) per kg of dry matter intake.

Labour productivity

The returns (income) from milk production and average productivity of inputs for small, medium and large categories of households are presented in Table 5.13. The average annual gross returns from milk production for small households was about Rs.43 thousand, while for medium it was almost double (Rs.88.7 thousand) and nearly four times higher (Rs.1 lakh, 74 thousand) for large category of households. The average productivity of labour calculated by dividing the value of milk output produced by the household per day (as captured through gross returns from milk production) by the mandays employed in dairy was Rs.309.42 for small households, Rs.335.42 for medium households and was even higher (Rs.419.36) for large households. The labour productivity ranged from Rs.132/man day to over thousand (Rs.1093/man day) on some households.

Table 5.13 Average productivity of inputs and annual returns from milk production.

(Rs./household)

Sl. No.	Particulars	Small	Medium	Large
(A)	Gross returns from milk output (Rs/annum)	43061.55	88694.61	174280.00
(B)	Net maintenance cost (Rs/annum)	41845.14	76431.53	140779.72
(C)	Net income (Rs/annum) (A-B)	1216.41	12263.08	33500.28
(D)	Imputed value of Family labour (Rs/annum)	8692.04	16454.12	26048.40
	Family labour income (Rs/annum) (A-B+D)	9908.46	28717.20	59548.68
(E)	Labour employed in dairy (Man days)	0.38	0.72	1.14
	Labour productivity (Rs./day) {(A/365)/E}	309.42	335.43	419.36
(F)	Total dairy Assets (Rs/annum)	32292.41	64072.44	113076.40
	Capital Productivity (%) (C/F)x100	3.77	19.14	29.63
(G)	Milk productivity (Lit)	4.29	4.64	4.96
(H)	Dry Matter Intake (DMI) in Kg.	10.00	10.31	10.37
	Feed productivity (Lit/Kg. DMI) (G/H)	0.43	0.45	0.48

Capital productivity

The average capital productivity was merely 4 percent per annum for small households; while for medium and large households, it was around 19 percent and 29.63 percent, respectively. The capital productivity was quite low on small herds because the net annual income was very low (Rs.1216) on these households. In fact, there were more than 44 percent of small households, where net income from milk production was negative. Although, some of medium and large households also had negative net return, but on an average the net annual income was higher than small households, and found Rs.12.2 thousand and Rs.33.5 thousand for medium and large households, respectively.

Feed productivity

The average dry matter intake per animal was by and large, similar across herd size categories ranging from 10 kg in small households to 10.37 kg on large households. Due to higher milk productivity on large category

(4.76 lit./day), feed productivity was highest for this households category. However, it may be noted that the average feed productivity of 0.5 indicating poor feed conversion efficiency of animals in general. Also the inter-households variations were very wide ranging from 0.21 to 0.93.

5.3.2.3 Economic sustainability : Aggregating the indicators

Based on the above indicators, the average score of economic sustainability computed for different herd size categories and the percent distribution of households based on the range of economic sustainability scores is given in Table 5.14.

Equal weights

The table revealed that the overall score of economic sustainability was on the lower side at 27.06. The inter-household variations were very wide (CV = 75.73%) as economic sustainability ranged from as low as 1.49 to as high as 79.45 on a 100-point scale. The close examination of table shows that 65 percent of total households were in the range of low economic sustainability score (<33.33) and merely 6 percent households were scored above in the range of top 1/3 scores.

The aggregate sustainability score increased from 21.69 on small herd size category to 28.61 on medium herd and further to 36.67 on large herds. The inter-households variations were also very high (CV = 93.61%) on small category of herd as compared to medium (CV = 65.74%) and large (CV = 55.73%). Further, it was observed that 75 percent of small households were in the range of low score of economic sustainability as against 61.54 percent for medium and 48 percent for large category of households.

Expert weights

Based on expert weights, i.e., on the scale of 0 to 138 points, almost similar findings were observed.

Table 5.14 Distribution of households according to level of total economic sustainability score.

Level of Score	Weighting pattern							
	Equal weights (100-point scale)				Based on experts opinion (138-point scale)			
	Small (N=56)	Medium (N=39)	Large (N=25)	Overall	Small (N=56)	Medium (N=39)	Large (N=25)	Overall
Low	42 (75.00)	24 (61.54)	12 (48.00)	78 (65.00)	42 (75.00)	22 (56.41)	13 (52.00)	77 (64.13)
Moderate	11 (19.64)	15 (38.46)	9 (36.00)	35 (29.17)	11 (19.64)	17 (43.59)	9 (36.00)	37 (30.83)
High	3 (5.36)	-	4 (16.00)	7 (5.83)	3 (5.36)	-	3 (12.00)	6 (5.00)
Overall (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Average Score	21.69	28.61	36.67	27.06	30.12	39.69	50.62	37.50
Range	1.49 to 79.45	3.06 to 62.09	4.01 to 72.61	1.49 to 79.45	2.37 to 114.89	4.85 to 86.16	6.36 to 100.97	2.37 to 114.89
C.V.	93.61	65.74	55.24	75.73	94.87	66.31	55.14	76.32

Figures in parentheses are the percentages of total no of households in respective category

Low = Range of scores bottom one-third; Moderate = Range of scores middle one-third; High = Range of scores top one-third.

5.3.3 Social Dimension

As stated earlier, the basic social requirements of sustainable dairy are that (i) farm households earn sufficient income from this enterprise, (ii) there should be no gender discrimination or gender bias and (iii) they work under the conditions that do not put their health at risk. Therefore, the proportion of family labour income as a percentage of MPCE, women empowerment and drudgery of work were used to capture the above three requirements.

5.3.3.1 Family labour income

As dairy enterprise mainly engaged family labour, it is important for the sustainability of this economic activity that it generates sufficient family labour income. The extent of adequacy of the family labour income was seen in terms of the monthly per capita consumption expenditure (MPCE) that can be met out of family labour income. The estimates of annual family labour income worked out to be Rs.9908 for small households category, about three times higher (Rs.28717) for medium households and 6 times higher (Rs.59548) for large households (Table 5.13). On per capita basis, the family labour income was about Rs.102, that is equivalent to nearly 17 percent of the MPCE of Rs.591 in rural Rajasthan (NSSO, 2006).

5.3.3.2 Women empowerment index

From times immemorial, women have played a pivotal role in our agriculture, in general and dairy, in particular. However, the role-played by women and their contribution to various economic activities in our country has yet to be given due importance. As women play predominant role in dairy farming, this enterprise can be sustainable from the social aspect if it is associated with empowerment of women. Therefore, women empowerment is taken into account for assessing social sustainability. Table 5.15 presents the average value of Women Empowerment Index (WEI) and frequency distribution of households according to the same.

Table 5.15 Women Empowerment Index (WEI) : Frequency distribution of households.

Range of Empowerment Index	Small (N=56)	Medium (N=39)	Large (N=25)	Overall (N=120)
Low	--	--	--	--
Moderate	56 (100.00)	37 (94.87)	24 (96.00)	117 (97.50)
High	--	2 (5.13)	1 (4.00)	3 (2.50)
Geometric mean	48.44	50.04	51.49	49.58
Range	39.66-66.38	39.87-73.43	40.45-71.76	39.66-73.43
C.V	12.81	13.26	15.00	13.59

Figures in parentheses are the percentages of total no of households in respective category

Low = Range of scores bottom one-third; Moderate = Range of scores middle one-third; High = Range of scores top one-third.

It was observed that the overall average WEI was around 50 and varied in the range of 39.66 to 73.43 and low coefficient of variation of 13.59 percent. The mean WEI values across herd size categories show very minor increase in the average index as herd size increased. The predominant number of women concentrated in moderate WEI range. By and large, the status of women was not so good among the sample households.

5.3.3.3 Drudgery of work

This aspect throws light on the labour condition associated with the economic activity. For an enterprise to be sustainable, it should be managed in a way that next generations may be willing to take it up. From this perspective, the drudgery involved in carrying out the economic activity becomes an important component as clearly higher drudgery would dissuade the younger generation in engaging themselves in the said economic activity.

In this context, the working condition of farmers was captured through three sub-indicators, viz., sharing of burden among the number of persons in each activity, manual carrying of weight / load and number of days that a main worker can stay away from the households. Appendix-XIIa and b presents the results obtained from these variables.

Work sharing

The various dairy activities were grouped into three : feeding, cleaning and milking. Out of these, as per the opinion of dairy farmers, cleaning involved maximum drudgery followed by feeding and milking. The most of the dairy activities were shared by two or more persons except milking, which was generally done by a single person (Appendix-XIIa).

Men carried out the activities such as selling of milk involving less drudgery, while the remaining were undertaken by women. The younger workers had to carry out the activities involving more drudgery, like cleaning, bringing fodder, etc.

Weight loaded

On an average, one person in dairy activity had to carry a load of 16.04 kg/day/km. But the inter-household variations in the carrying of weight per person were very wide. On some household, it was only half a kg while on others it was as much higher as over 40 kg/day/km (Appendix-XIIb).

Days off work that a main worker can afford

The average number of days off work affordable by main worker was found only 17 days in a year (Appendix-XIIb) indicating the higher drudgery in dairy. Despite of large family size, the days off work affordable by main worker were low for large category of households (14.27 days) as compared to medium (17.54 days) and small (18.43 days). This could be probably due to large milch herd on large category.

5.3.3.4 Social Sustainability : Aggregating the Indicators

Equal weights

Unlike economic sustainability where inter-household variations were very large (C.V. = 75.75%), in social sustainability, inter-households variations are of low magnitude (C.V. = 24.04%). The average score is in the range of 33 to 41, i.e., households were moderately social sustainable and the higher end of score was 63.45. Nearly 57 percent of households were in the moderate range (middle 1/3rd range) of scores, while rest were in low range (bottom 1/3rd range). As the upper end of scores was 63.45, obviously none of the household scored in higher range of scores (top 1/3rd range) (Table 5.16).

With the increase in size of herd, the average score of social sustainability also increased from around 33 for small households to 40.62 for large category of herds. The inter-household variations were relatively more on medium category of households (C.V. = 25%) as compared to large (C.V. = 22%) and small categories of households (C.V. = 21%).

Expert weights

Similar to the aggregate economic sustainability scores, the social sustainability scores also showed the same pattern of distribution of households based on expert weights.

5.3.4 Ecological Dimension

The nature of interaction of biological production systems with environmental is a very crucial determinant of the sustainability of the production system itself. Such interactions between dairy farming and environment are captured using three variables : ratio of dung utilization for fuel to manure, enteric methane emission from dairy animals, and breeding practices followed by farmers.

5.3.4.1 Utilization of dung

The use of dung for manure purpose is environment friendly, while its use as fuel poses both, environmental and human health hazards. The

Table 5.16 Distribution of households according to level of total social sustainability score.

Level of Score	Weighting pattern							
	Equal weights (100-point scale)				Based on experts opinion (90-point scale)			
	Small (N=56)	Medium (N=39)	Large (N=25)	Overall	Small (N=56)	Medium (N=39)	Large (N=25)	Overall
Low	30 (53.57)	16 (41.03)	6 (24.00)	52 (43.33)	30 (53.57)	17 (43.59)	9 (36.00)	56 (46.67)
Moderate	26 (46.43)	23 (58.97)	19 (76.00)	68 (56.67)	26 (46.43)	22 (56.41)	16 (64.00)	64 (53.33)
High	-	-	-	-	-	-	-	-
Overall (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Average Score	32.97	36.54	40.62	35.72	29.62	32.69	36.31	32.01
Range	20.12 to 50.89	22.09 to 63.45	28.89 to 60.05	20.12 to 63.45	17.86 to 46.38	19.15 to 56.65	25.07 to 53.45	17.46 to 56.65
C.V.	21.17	24.72	22.17	24.04	22.43	25.78	22.39	24.82

Figures in parentheses are the percentages of total no of households in respective category

Low = Range of scores bottom one-third; Moderate = Range of scores middle one-third; High = Range of scores top one-third.

data for dung production and its utilization were collected from each household and the ratio for fuel to manure was computed. Mostly dung was used for manure and only about 27 percent was used as fuel (Table 5.17). On the small herd size category the average landholding was also small (1.39 ha), relatively lower percentage was used as manure and about one-third was burnt as fuel.

Table 5.17 Percentage distribution of households based on proportion of dung used as fuel.

Average dung utilization as fuel	Small	Medium	Large	Overall
Average	33.29	23.09	17.76	26.74
Low (< 33%)	38 (67.86)	31 (79.49)	24 (96.00)	93 (77.50)
Medium (33-66%)	15 (26.79)	8 (20.51)	1 (4.00)	24 (20.00)
High (>66%)	3 (5.36)	-	-	3 (2.50)

Figures in parentheses indicates percentages to total.

5.3.4.2 Enteric methane emission

Enteric methane emission accounted for about 17 percent of national Green House Gas (GHG) emissions and 60 percent of the GHG emissions from agriculture sector (NATCOM, 2004). Methane has 21 times more global warming potential than carbon dioxide but a relatively short chemical lifetime of about 12 years compared to 120 years of CO₂. It has been identified as one of the six GHG, which need to be stabilized to mitigate global warming and resulting climate change. Besides, its role as GHG, reducing enteric methane emissions is also important for improving the rumen fermentation efficiency. In general, in ruminants, 8 to 12 percent of dietary energy is lost in form of methane (Blaxter, 1967). As the losses of methane represent inefficiencies and losses of energy in our current production system, it therefore stands to reason that estimates of enteric methane emission have long-run implications for sustainability of dairy farming besides being very crucial from standpoint of global climate.

Methane production from animals as a result of enteric fermentation depends upon quality and quantity of feed consumed by them. The enteric methane emission factor for dairy animals, estimated for the study area based on the quantity and type of feed was multiplied by the number of animals in respective category to get the methane emission for each household. The estimate of methane emission from dairy animals thus obtained was divided by household milk production to get the methane emission per litre of milk produced.

The methane factor for lactating local cow, crossbred cow and buffalo was 52.63, 74.38 and 72.42 kg methane/head/year, respectively, while dry local cow, crossbred cow and buffalo emitted 45.57, 69.45 and 63.41 kg methane/head/year (Appendix-XIII). The higher per head emission of methane by lactating animals as compared to dry animals was attributed to the fact that households fed less to the non-producing animals (Appendix-XIII). Similarly, emission level was higher due to their better feeding by the farmers for crossbred cow owing to higher milk yield potential. The differences across species and production stages of animals was also found by Karunanithi (2004) in a more comprehensive study on enteric methane emissions.

The methane emission in relation to milk production ranged from 26.3 g to 95.2 g per litre with an overall average of 42 g per litre (Table 5.18). Across herd size categories, the emissions decreased from 44.2 g per litre on small to 40.3 g per litre on medium and further to 39.8 g per litre on large. The lower emission on larger herds was attributable to greater milk production and productivity of dairy animals.

Table 5.18 Average methane emission.

Herd size	Methane emission (g/lit of milk)
Small	44.20
Medium	40.30
Large	39.80
Overall average	42.00
Maximum	95.20
Minimum	26.30

5.3.4.3 Breeding practices

The dairy farmers were interviewed to assess the breeding practices, followed by them. It was found that only Artificial Insemination (AI) method of mating was practised for crossbred cow, whereas, for buffalo, natural services were usually resorted to. In case of local cow, both natural services and AI were practised but the rate of adoption of AI was low (42%).

The system of mating was indiscriminate (unplanned) on around half of the households for cows. Nearly 1/3rd of the farmers were using the scrub bull, i.e., no specific breed characteristics, for natural services and their percentage was as high as 43.63 percent on small households (Appendix-XIVa).

The male calves were generally sold before one year of age due to low demand of draft power animals. The rate of castration of male calves was high (79%), and methods of castration were not scientific in the study area.

The problem of repeat breeding was observed in about 14 percent of households in either one or two animals in a year (Appendix-XIVb). There were 6 percent of households in which the cases of abortion of animals was found and in most of them in later part of pregnancy (>6 months), which was very dangerous.

Besides these, the breeding infrastructural facilities were not proper in the sample villages (Appendix-XIVc). Out of the four villages, the AI centre, trained inseminator, quality semen, veterinary doctor and village panchayat bull was available in only one village and for 3 villages, these facilities were available about 2 to 4 km away from villages. There was no availability of liquid nitrogen canes and medicines in any village. The village panchayat bull available in only one village was non descriptive in case of cow and of Murrah breed for buffalo.

The index aggregated from these practices based on their implication for sustainability was only around 51 and ranged from 48.16 on small category of households to 55.47 on large category (Appendix-XIVa).

Thus, It may be concluded that the breeding practices followed by farmers were not scientific in nature.

5.3.4.4 Ecological sustainability : Aggregating index

Equal weights

The average ecological sustainability score was 49.70 with low inter-household variations (CV = 25%) indicating that the ecological sustainability is relatively better than the economic and social sustainability. The average score ranged from 45.15 on small category of households to 54.89 on large category (Table 5.19). The inter-household variations were relatively higher on smaller households (CV = 27%) as compared to medium and large households (around 21%).

Most of the households (86.67%) were in the moderate range of ecological sustainability, and a few (9.17%) were in high range. The percentage of households in high range of ecological sustainability was higher (16.00%) as compared to medium (12.82%) and small (3.37%).

Expert weights

Based on expert weights to indicators and dimensions, i.e., on 72-point scale, the average score as well as pattern of distribution has changed. The aggregate ecological sustainability score was imposed to 47.78 and ranged from 44.62 on small households to around 52 on large size category. The inter-household variations were also in the narrow range (CV = 13.9%) and was still low for large category (CV = 7.53%).

The expert weights also changed the pattern of distribution of households. The proportion of households in high range of ecological sustainability increased to around 56 percent as against only 9 percent based on equal weights, and it was as high as 92% in case of large category of households.

Table 5.19 Distribution of households according to level of total ecological sustainability score.

Level of Score	Weighting pattern							
	Equal weights (100-point scale)				Based on experts opinion (72-point scale)			
	Small (N=56)	Medium (N=39)	Large (N=25)	Overall	Small (N=56)	Medium (N=39)	Large (N=25)	Overall
Low	4 (7.14)	1 (2.56)	-	5 (4.17)	2 (3.57)	-	-	2 (1.67)
Moderate	50 (89.29)	33 (84.62)	21 (84.00)	104 (86.67)	34 (60.72)	15 (38.46)	2 (8.00)	51 (42.50)
High	2 (3.37)	5 (12.82)	4 (16.00)	11 (9.16)	20 (37.71)	24 (61.54)	23 (92.00)	67 (55.83)
Overall (%)	56 (100.00)	39 (100.00)	25 (100.00)	120 (100.00)	56 (100.00)	39 (100.00)	25 (100.00)	120 (100.00)
Average Score	45.15	52.90	54.89	49.70	44.62	49.55	52.08	47.78
Range	11.88 to 75.33	33.10 to 78.35	38.18 to 83.47	11.88 to 83.47	14.04 to 54.77	39.91 to 58.28	41.70 to 59.35	14.04 to 59.35
C.V.	27.37	21.33	20.83	25.17	16.56	8.88	7.53	13.90

Figures in parentheses are the percentages of total no of households in respective category.

Low = Range of scores bottom one-third; Moderate = Range of scores middle one-third; High = Range of scores top one-third.

Fig. 5.5 Scatter diagram of SDFI across herd size.

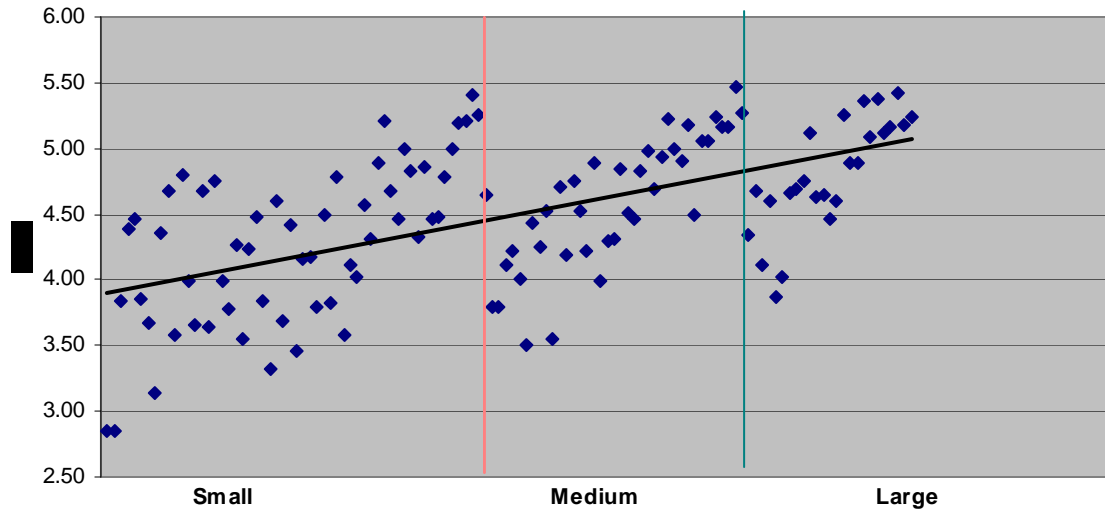
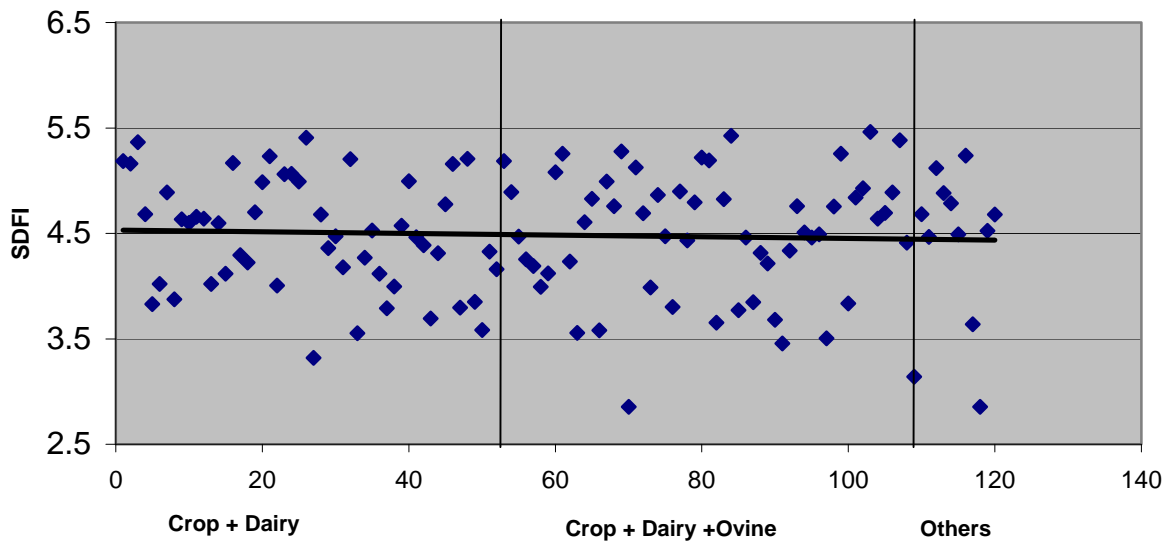


Fig. 5.6 Scatter diagram of SDFI across farming systems category.



5.3.5 Composite Sustainable Dairy Farming Index (SDFI)

Equal weights

The composite sustainability index was estimated by taking into account all the three dimensions discussed above. The full scores in each aspect of sustainability would result in a maximum of Sustainable Dairy Farming Index (SDFI) to 6, while minimum would be SDFI = 0. The average value of SDFI as well as distribution of households based on the value of SDFI across herd size category is presented in Table 5.20.

The overall average value of SDFI was 4.48, ranging from 2.86 to 5.46. The inter-household variations were low (CV = 12.93%) and were estimated to be the lowest for large category of households (CV = 8.97%), followed by medium and small categories with coefficient of variations 10.89 and 14.22 percent, respectively. More than 3/4th of the households (77.5%) had moderate SDFI score ranging from 3 to 5. Interestingly, almost all the remaining households (20.8%) were high scorers suggesting that dairy farming had lineage towards sustainability.

The aggregate SDFI increased with increasing herd size category. It was 4.26 on small households, increased to 4.59 on medium and further to 4.81 for large category of households. The Figure 5.5 further substantiates the results. Among the high sustainable households 80 percent were medium and large. The direct relation of SDFI which herd size category suggested that the households could improve the sustainability of dairy farming by maintaining large herd.

Expert weights

Though, the SDFI based on expert weights was slightly higher (4.58) with low variations, the pattern of distribution was almost same as in case of SDFI based on equal weights.

The distribution of households based on the range of sustainable dairy farming index across farming system categories is given in Table 5.21 and plotted on scatter diagram (Fig. 5.6). The table shows that the SDFI index did not vary across the farming systems and distribution of households was almost equal. From this, it can be concluded that farming system did not have any effect on sustainability of dairy farming.

Table 5.20 Distribution of households based on level of aggregate Sustainable Dairy Farming Index (SDFI) across herd size categories.

Level of Score	Weighting pattern							
	Equal weights (100-point scale)				Based on experts opinion			
	Small (N=56)	Medium (N=39)	Large (N=25)	Overall	Small (N=56)	Medium (N=39)	Large (N=25)	Overall
Low	2 (3.57)	-	-	2 (1.67)	-	-	-	-
Moderate	49 (87.50)	29 (74.36)	15 (60.00)	93 (77.50)	50 (89.29)	28 (71.79)	15 (60.00)	93 (77.50)
High	5 (8.93)	10 (25.64)	10 (40.00)	25 (20.83)	6 (10.71)	11 (28.71)	10 (40.00)	27 (22.50)
Overall (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Average Score	4.26	4.59	4.81	4.48	4.37	4.67	4.89	4.58
Range	2.86 to 5.41	3.51 to 5.46	3.87 to 5.43	2.86 to 5.46	3.09 to 5.31	3.70 to 5.40	4.07 to 5.41	3.09 to 5.41
C.V.	14.22	10.89	8.97	12.93	12.35	9.38	7.64	11.27

Figures in parentheses are the percentages of total no of households in respective category

Low = (<3); Moderate (3-5); High (\geq 5)

Table 5.21 Distribution of households based on the range Sustainable Dairy Farming Index (SDFI) across farming systems categories.

Level of Score	Weighting pattern							
	Equal weights (100-point scale)				Based on experts opinion			
	Crop+ Dairy (N=52)	Crop+ Dairy + Ovine (N=57)	Others (N=11)	Overall	Crop+ Dairy (N=52)	Crop+ Dairy + Ovine (N=57)	Others (N=11)	Overall
Low	-	1 (1.75)	1 (9.09)	2 (1.67)	-	-	-	-
Moderate	40 (76.92)	45 (78.95)	8 (72.73)	93 (77.50)	39 (75.00)	45 (78.95)	9 (81.82)	93 (77.50)
High	12 (23.08)	11 (19.30)	2 (18.18)	25 (20.83)	13 (25.00)	12 (21.05)	2 (18.18)	27 (22.50)
Overall (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Average Score	4.48	4.48	4.49	4.48	4.56	4.58	4.60	4.58
Range	3.32 to 5.41	2.86 to 5.46	2.86 to 5.43	2.86 to 5.46	3.49 to 5.41	3.09 to 5.40	3.20 to 5.21	3.09 to 5.41
C.V.	11.87	13.63	15.22	12.93	10.32	11.99	12.78	11.27

Figures in parentheses are the percentages of total no of households in respective category

Low = (<3); Moderate (3-5); High (\geq 5)

5.4 DETERMINANTS OF SUSTAINABLE DAIRY FARMING

Having quantified the sustainability status of dairy farming at household level, the factors affecting sustainability are analyzed. The knowledge of determinants of sustainability shall help policy maker as well as farm households to improve the sustainability of dairy farming in the study area.

Sustainability of dairy farming may depend upon large number of factors. This section is directed to examine the empirical nature of relationship between SDFI and its determinants. Taking SDFI as the dependent variable, the explanatory variables considered were, ratio of buffalo and crossbred cow to local cow (RBCLC), milk yield of households (in litres) (MY), proportion of milch animals up to 3rd lactation (III_lac), marketed surplus of households (MS), size of operational land holding (hectares) (SIZE), per animal area under fodder crops (hectares) (FODDER), proportion of variable expenses on concentrates (CONS), proportion of curative veterinary expenses to total veterinary expenses (VET), education index of household (EDU) and index of extension contact (EXT). Except the variable VET, which is postulated to have negative relation with SDFI, all other variables are hypothesized to have positive effect on the dependent variables. The detailed *a-priori* logic for selection of variables and their expected signs are already discussed in the methodology of the study.

The zero-order correlation coefficients of SDFI and the explanatory variables (Table 5.22) substantiate the postulated *a-priori* relationship as the signs of all the correlation coefficients are in consonance with the expected signs. In other words, the data provide support for preceding hypothesis about the relationship of these variables.

The zero-order correlation matrix also showed that 6 variables out of 10 explanatory variables had significant correlation with SDFI. These variables were MY ($r = 0.84$), MS ($r = 0.56$), CONS ($r = 0.55$), RBCLC ($r = 0.26$), SIZE ($r = 0.23$) and EXT ($r = 0.20$).

Table 5.22 Zero-order correlation matrix.

	SDFI (with equal weights)	RBCLC	MY	III_LAC	MS	SIZE	FODDE R	VET	CONS	EDU	EXT
SDFI											
RBCLC	0.26***										
MY	0.84***	0.31***									
III_LAC	0.17	0.01	0.10								
MS	0.56***	0.40***	0.43***	0.12							
SIZE	0.23**	0.22*	0.17	0.09	0.20*						
FODDER	0.01	0.10	0.11	-0.02	0.01	0.08					
VET	-0.11	0.12	-0.12	-0.01	0.02	-0.01	0.08				
CONS	0.55***	0.16	0.63***	0.06	0.27***	0.10	0.19*	0.01			
EDU	0.11	0.10	0.02	-0.10	0.12	0.13	0.14	0.02	0.02		
EXT	0.20*	0.03	0.24***	-0.17	0.13	0.15	0.18*	-0.07	0.20*	0.22*	

*** = $P \leq 0.01$; ** = $P \leq 0.05$; * = $P \leq 0.1$

The regression results brought out that these 10 explanatory variables together explained 77.75 percent variation in SDFI (Table 5.23). Milk yield emerged as the most significant variable affecting sustainability. This is quite obvious as higher milk yield, *ceteris-paribus*, means greater productivity of inputs (particularly feed input), lower cost of milk production, greater family labour income, lower enteric methane emissions per litre of milk produced – that is directly and indirectly it improves the economic, social and ecological dimensions of sustainability.

Table 5.23 Factors affecting sustainability of dairy farming.

Variables	Coefficients	t-Stat
Intercept	2.39158	10.72842
RBCLC	-0.00215	-1.51192
MY	0.34679***	11.10548
III_LAC	0.00150	1.44519
MS	0.00660***	4.49741
SIZE	0.01556	1.29806
FODDER	-3.00284*	-1.67568
VET	-0.00017	-0.28172
CONS	0.00390	0.74705
EDU	0.05807*	1.74625
EXT	-0.00048	-0.14827
R-square	0.77755	
Adjusted R-square	0.75715	
No. of observations	120	

*** = $P \leq 0.01$; * = $P \leq 0.10$

The other important variable affecting sustainability was marketed surplus that denotes percentage of milk output sold by the households. This variable captures the market orientation of the households. Undoubtedly, greater access to market has direct positive bearing on the economic dimension of sustainability. All the same time, it may also be critical in

bringing out structural changes in the society such that greater income and more commercial nature of dairy farming empower women who are the main workers in dairy enterprise.

Education of households and available area under fodder crops per animal also showed somewhat weak significance ($P \leq 0.10$) with the explanatory variable, although the sign of the regression coefficient of the later variable was contrary to the *a-priori* hypothesis.

The importance and relevance of education in improving the sustainability of any production system need no emphasis and has also been brought out by the data in the present study the point that need to be emphasized here is that vocational training and other short and medium term trainings regarding scientific dairy farming practices particularly to women folk can be instrumental in enhancing the sustainability of this labour intensive enterprise. Also, the education of females deserves high priority in the state of Rajasthan as female literacy level is quite low in the state.

The inverse nature of relationship between FODDER and SDFI in the regression equation has its roots in the collinearity of this explanatory variable with other independent variables. Therefore, despite a positive zero-order correlation coefficient, the regression coefficient is negative. Similarly, for two other explanatory variables (RBCLC and EXT), the interaction amongst independent variables (Table 5.22) leads to different signs of regression coefficient vis-à-vis correlation coefficient. However, both these explanatory variables are insignificant in the regression estimates.

It was hypothesized that the proportion of curative veterinary expenses to total veterinary expenses (VET) is negatively correlated with the SDFI, but from the data, the coefficient of VET was not found statistically significant and with expected sign. The non-significance of this variable seems to be because low veterinary expenses as also signifies from the low veterinary and miscellaneous cost components in cost of milk production.

Furthermore, index of extension contact did not have significant impact on sustainability. The low level of extension contact and communication facilities in the study area could be possible reason of non-significant relationship between extension contact and SDFI.

Due to considerable collinearity between explanatory variables, in the step-wise regression, only 3 explanatory variables were found significant these were milk yield, animals up to 3rd lactation and education (Table 5.24).

Table 5.24 OLS estimates of step-wise regression.

Variables	Coefficients	t-Stat
Intercept	2.35165	14.94816
MY	0.39711***	16.79022
III_Lac	0.00219**	1.99875
EDU	0.06989**	2.02269
R-square	0.7213	
Adjusted R-square	0.7141	
No. of observations	120	

*** = $P \leq 0.01$; ** = $P \leq 0.05$

The milk yield also determined expenditure on concentrates as higher concentrate feeding higher will be the milk yield. This is also evident from significant high correlation coefficients of 0.63 (Table 5.22). The milk yield was also correlated with the variable, ratio of crossbred cattle and buffalo to local cow. Therefore, the sustainability can also be improved by better concentrate feeding and by rearing more productive animals such as crossbred cattle and buffaloes in the herd.

It emerged from the discussion that the milk yield is major determinant for improving the sustainability, which can be enhanced through improved technologies. The good marketing facilities and extension services in village can also improve the sustainability directly or indirectly.

6. SUMMARY AND CONCLUSIONS

The topic of sustainability in production process has widely engaged the attention of researchers, but very few attempts have been made in crop sector and much fewer in livestock to address the relevant issues with empirical firmness. Measurement happens to be the weakest aspect of sustainability due to huge database requirement and complex analytical framework.

The present study is a step forward in the direction of quantitative assessment of the sustainability of livestock production system, comprehensively covering the state of Rajasthan. Given the importance of livestock in the arid state of Rajasthan in insulating the income of farmers against the vagaries of nature and resulting frequent drought in the state, coupled with constraints, like low productivity of animals, low availability of livestock feed, shrinking grazing lands, inhospitable climate of arid ecosystem, impoverished fragile resources, etc. sustainability becomes a very important issue in Rajasthan.

The present study **“Sustainability Assessment of Livestock Production System in Rajasthan”** was undertaken with the broad objectives of delineating research and policy implications for enhancing the sustainability of livestock production in Rajasthan with the help of following specific objectives:

- (I) To measure the Total Factor Productivity (TFP) growth in livestock sector in Rajasthan.
- (II) To examine the economic, social and ecological sustainability of livestock production across various agro-climatic zones and districts of the state.

- (III) To evaluate the socio-economic and ecological dimensions of sustainable dairy farming on sample households.
- (IV) To study the factors affecting sustainability of dairy farming in the study area.

The study was conducted both, at macro and micro level. At the macro level, TFP of livestock sector was estimated for the state as a whole and regional variations across various indicators of sustainability livestock production were examined. At micro level, the study evaluated the sustainability of dairy farming in purposively selected sample district of Jaipur, and analyzed the determinants of sustainability. The secondary data were collected on various parameters like value, production and prices of various livestock products as well as socio-economic, demographic and other characteristics from various published and unpublished sources. The primary data were collected for three seasons (summer, rainy and winter) for the year 2006-07 from 120 selected households through personal interview. The collected data were analyzed to assess the sustainability using two major tools namely, TFP and composite encompassing indexing economic, social and ecological dimensions of the sustainability. The multiple regression analysis was carried out to identify the determinants of sustainability.

The main findings of the study are summarized as follows :

The total value of output from livestock sector in Rajasthan registered a compound annual growth rate of 11 percent at current prices, while in real terms the growth was only 2 percent during 1960-61 to 2004-05. Milk and milk products constituted the highest share in total value and the percentage share increased from 45 percent in 1960-61 to around 65 percent in 2004-05.

The total value of livestock inputs also registered a compound annual growth rate of about 2 percent per annum in real terms during 1960-61 to 2004-05. The share of feed component was highest in value of inputs followed by labour and interest on population stock.

In general, total output and input indices moved together, except in years of drought when input indices dropped sharply but output either remained unchanged or showed marginal increase. This clearly indicates that livestock was a coping mechanism in the eventuality of drought. The marginally higher compound annual growth of 2.26 percent in output index as compared to 1.99 percent growth in input index led to negligible growth in TFP indicating that the overall sustainability status of livestock production is not encouraging in the state. The output growth has been largely input driven, which will be difficult to sustain, if appropriate technological improvement does not take place. The upswing in TFP after the 1990's, discernible from the growth rate of 1.99 percent in TFP during 1990-91 to 2004-05 needs to be maintained to enhance the sustainability of this important sector for rural households.

The results of Sustainable Livestock Production Index (SLPI) computed for agro-climatic zones and districts also substantiated the broad conclusions drawn from TFP analysis. The mean value of SLPI was 0.39, much lower than the maximum obtainable value of 1.00, indicating that in general, the sustainability status of livestock production is low in Rajasthan. The inter-zonal variations in SLPI are not very high (CV = 21.6%). The irrigated north-western plain zone comprising the districts of Ganganagar and Hanumangarh is the top ranking zone with SLPI of 0.55, followed by semi-arid eastern plain (SLPI = 0.454) and flood prone eastern plain (SLPI = 0.377). The worst performing zones were southern and south-eastern plain, and south plain and Aravali hills with very low SLPI of 0.292 and 0.338, respectively.

Among the various dimensions of sustainability, ecological aspect is the weakest in all the zones, while the economic aspect is strongest (except southern and south-eastern plain, and southern plain and Aravali hills zones). From the policy perspective, although all the zones need attention for livestock development but the agro-climatic zone with very low sustainability indices, viz., southern and south-eastern plain should receive top priority. Based on the results of individual dimensions, it can be inferred that the

southern plain and Aravali hills required policy focus on improving economic efficiency, while in case of southern and south-eastern plain zone, programmes should be focused towards strengthening ecological security.

At the district level, the weighted Sustainable Livestock Production Index (SLPI*) ranged from a low level of 0.114 in Dungarpur district to a moderate level of 0.495 in Hanumangarh district. Almost half of the districts were low in their sustainability ($SLPI^* < 0.3$), while remaining half were in medium range ($0.3 < SLPI^* < 0.5$) and none of the district crossed the value of 0.5.

Among the low SLPI* districts, Swai Madhopur performed poorly in all the three dimensions. In other districts with overall low SLPI*, the performance was not consistently poor across all dimensions as in Swai Madhopur.

The districts of Dungarpur, Banswara, Chittorgarh, Jhalawar, Kota, Bhilwara and Barmer had low economic and ecological indices (< 0.3), while Jalore and Tonk were particularly poor in social equity and ecological security. A few districts like, Baran and Udaipur, Nagaur, Bharatpur and Pali showed overall low SLPI* index largely due to poor performance of single dimension.

Among the moderate SLPI* districts, except Churu in economic and Jaisalmer in social aspect, all the districts performed very well ($SLPI^* \geq 0.5$) or moderately well ($0.3 < SLPI^* < 0.5$) in these two dimensions. The ecological dimension was relatively weak for most of these districts.

The analysis of economic indicators of sustainable dairy farming at household level brought out that the overall cost of milk production was lowest for crossbred cow (Rs.9.38/lit.), followed by local cow (Rs.11.69/lit.). The average labour productivity in terms of gross returns from milk per manday was over Rs.300 on households of different herd size categories. But the capital productivity was quite low for small herd size category farms (4%), while for medium and large household, it was about 17 and 30 percent, respectively.

The aggregate economic sustainability score, in general, was low (27.06) and inter-households variations were very wide (CV = 75.73%) as economic sustainability score ranged from as low as 1.49 to as high as 79.45 on 100-point scale.

The indicators of social sustainability showed that in dairy enterprise per capita family labour income of about Rs.102 equivalent to nearly 17 percent of the MPCE in rural Rajasthan was generated.

Dairy was predominantly carried out by females but their empowerment status was low. On a 100-point scale, the mean value of empowerment index was 50 and most of the households were in the middle 1/3rd range of index.

The average of social sustainability scores ranged from 33 on small herd size to 41 with large households showing low to moderate status of households from social aspect.

The three indicators of ecological dimension of sustainability exhibited very interesting results. The dung utilization pattern was quite eco-friendly in the region, as it was mostly used for manure and only about 27 percent was used as fuel.

The methane emissions in relation to milk production ranged from 26.3 to 95.2 g/lit. with an overall average of 42 g/lit. being less than the corresponding figures of all-India average (50 grams) reported by other researchers.

However, the breeding practices followed by farmers in the study area were not of scientific nature to be sustainable in the longer run, largely due to inadequate availability of efficient support services.

The average ecological sustainability score was 49.70, higher than the corresponding average scores of economic and social dimensions. The results suggest that at the farm level, the management of dairy animals is not so much in conflict with the ecological sustainability criterion as had emerged at the macro level, where ecological security index of livestock production was poor for almost all the districts.

The composite Sustainable Dairy Farming Index (SDFI) taking into account, all the three dimensions of sustainability ranged from 2.86 to 5.45. More than 3/4th of the households (77.5%) had moderate SDFI index ranging from 3 to 5, while almost all the remaining households (20.3%) were high scorers suggesting that dairy farming had lineage towards sustainability in the Jaipur district of the state, which would be enhanced further through prioritizing the policy and investment on the weak indicators pointed out in the study.

The aggregate SDFI increased with increasing herd size category suggesting positive relationship between commercialization of dairy farming and sustainability of production system.

The scores as well as the distribution of households based on expert weights did not significantly differ for composite SDFI as well as various dimensions except ecological sustainability score. Based on expert weights, the ecological sustainability scores improved and distribution changed in era of large households.

Milk yield was found to be the major determinant. Besides this, marketed surplus, education and availability of fodder was also found significantly affecting sustainability. Milk yield was determined by the variables, expenses on concentrates, and ratio of crossbred cow and buffalo to local cow as correlation coefficient was very high among these variables and milk yield. Therefore, sustainability can be improved by improving milk yield through better technology and feeding. Good marketing facilities, extension network and vocational trainings for women are required for sustainable dairy farming.

CONCLUSIONS AND SUGGESTIONS

The findings of the present study has several implications for the sustainable development of livestock in general and dairying in particular in the study area, which are as follows :

The total factor productivity growth rate was found to be very low, i.e., the output growth was largely input driven, which could not be sustained for the

long period. Therefore, more attention should be given on technological advancement in the form of research and development. Also the livestock support services and institutional framework should be strengthened.

There were wide regional variations in the sustainability of livestock production and hence agro-climatic / district livestock plan should be formulated for sustainable development at the aggregated level. The Sustainable Livestock Production Index (SLPI) helps for such inter-regional priority of livestock investment and also to prioritize programmes / projects related to each region. Though all the zones need attention but the southern zone and south-eastern plain should receive top priority.

Among the various dimensions of sustainability, the ecological aspect is the weakest aspect in all the zones. Therefore, at agro-climatic zone level, more policy focus should be on conservation of forest, pasture and grazing lands and to decrease the livestock population.

The southern and south-eastern districts of Dungarpur, Udaipur, Chittorgarh, Banswara, Baran and Kota with Churu and Jaisalmer districts of western region were the poorest in all the three indicators of economic dimension, and therefore, Research and Development focus should be on improving the productivity of livestock by the improved technologies of crossbreeding, better feeding, healthcare facilities, etc.

The districts of Jalore, Banswara, Dungarpur, Jaisalmer and Tonk were the five bottom ranking districts in the indicator of female literacy rate of social dimension and hence efforts should be made to improve the literacy rate among the women. The investment priority of livestock infrastructural facilities such as AI center, veterinary hospital and dispensaries, extension centers should be channelized in the entire arid-western plain zone consisting of the districts of Jaisalmer, Barmer, Bikaner, Jodhpur and Churu.

In the districts of Kota, Swai Madhopur, Tonk, Dausa and Jaipur, the social sustainability is poor because of shrinking common property resources, and immediate attention should be given on conservation of these resources.

In the districts of Udaipur, Banswara, Jaipur, Alwar and Chittorgarh, the livestock population is surplus in relation to feed and fodder availability and creating environmental pressure. To cope up with this problem, immediate policy direction is required to increase the availability of fodder or to reduce the population of unproductive animals in these districts. More emphasis should be given on conservation of pasture and grazing lands in the districts of Hanumangarh, Churu, Nagaur, Ganganagar and Bharatpur as this indicator is poor in these districts.

At household level, the economic dimension of sustainability of dairy farming was poor due to higher cost of milk production and low productivity of inputs, particularly the feed input. Therefore, there is a case of providing good quality of feed and fodder at reasonable price to improve the productivity of feed and other inputs, and to reduce the cost of milk production, as the feed was the major component of total cost. The reduction in cost will also increase the family labour income and thereby social sustainability.

The status of women was observed to be weak and hence could be improved by providing better education and particularly through adult education programme. Improved education level will help and encourage them for active involvement in various development programmes. The women should be given equal opportunities and rights to have control over resources and access to household income through legislation for women empowerment.

Due to the more drudgery involved in the dairy activities, the people particularly the educated youth are taking up white collar jobs. Therefore, there is a need to develop operation specific and mechanical technologies so as to improve their efficiency and reduce drudgery.

Although the dung was largely used for manure, there is still scope to use it for biogas plants, which generate the gas as a cooking fuel as well as the manure to the crop farming.

The breeding practices in the study area were unscientific in nature. Therefore, farmers should be motivated to adopt breeding practices on scientific guidelines to make dairy farming sustainable. This could be possible only by adequate livestock support services like veterinary hospital, AI centre, extension services, awareness among the farmers, etc.

Milk yield emerged as the most significant variables affecting sustainability followed by marketed surplus of milk, education status and area under fodder. Therefore, sustainability can be improved by improving milk yield through better technology and feeding. Good marketing facilities, extension network, vocational trainings for women are required for sustainable dairy farming.

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APPENDIX –II**AVERAGE YIELD RATES OF MEAT PRODUCTS AND BY-PRODUCTS**

Product / Byproducts	Average Yield Rates (Kg.)		
	Cattle / Buffalo	Goat / Sheep	Pig
Edible offal, glands	4.44/5.09	0.71/0.57	1.574
Heads	5.89/7.31	0.813/0.72	3.485
Legs	4.89/6.09	0.501/0.49	1.042
Fats	4.81/8.97	0.289/0.16	3.003
Esophagus	0.21/0.31	0.073/0.03	0.185
Blood	8.28/8.84	0.769/0.49	2.267
Tail stumps	0.88/0.68	-	-
Bones	11.83/14.31	-	-
Guts	3.39/4.22	0.642/0.76	2.031
Horns	0.54/1.28	0.075/0.05	-
Hoofs	0.35/0.34	0.60	0.157
Useless meat	2.97/6.56	0.348/0.20	0.79

Source: National Accounts Statistics-Sources & Methods, 2007

AVERAGE BODY WEIGHT OF DIFFERENT ANIMALS

Categories	Body Weight (Kg)	Categories	Body Weight (Kg)
Crossbred Male		Crossbred female	
Calves < 1 year age (70%)	79	Calves < 1 year age (70%)	81.5
Calves 1-3 years age	174.5	Calves < 1-3 years age	179.5
Breeding bulls	317	Milking cows	326
Working bulls	317	Dry cows	326
Breeding + working bulls	412	Heifers	179.5
Others	301	Others	265
Indigenous Cattle Male		Indigenous Cattle female	
Calves <1 year age (70%)	72.5	Calves <1 year age (70%)	70
Calves 1-3 years age	146.5	Calves < 1-3 years age	146.5
Breeding bulls	290	Milking cows	266.5
Working bulls	290	Dry cows	281.5
Breeding + working bulls	290	Heifers	225
Others	266	Others	265
Buffaloes Male		Buffaloes female	
Calves < 1 year age (70%)	75	Calves < 1 year age (70%)	90
Calves 1-3 years age	180	Calves < 1-3 years age	198
Breeding bulls	512.5	Milking buffaloes	458
Working bulls	512.5	Dry buffaloes	458
Breeding + working bulls	512.5	Heifers	298
Others	475	Others	345.5
Goats Male		Goats Female	
< 1 year age (70%)	15.25	< 1 year age (70%)	15.25
1-2 years age	19.5	1-2 year age	18.8
Sheep Male		Sheep Female	
< 1 year age	18	< 1 year age (70%)	18
1-2 years age	35	1-2 year age	27.5
Camel	300	Horses & Ponies Male	
Pigs	70	<3 Years	200
Donkey	150	>3 Years	300

Source : Singhal *et al.* (2002)

APPENDIX-IIIb**DRY MATTER INTAKE (KG/100 KG. BODY WEIGHT) OF DIFFERENT CATEGORIES OF ANIMALS**

Age	Male Crossbred	Male Indigenous	Male Buffalo	Male Sheep	Male Goat
0-1 year	2.5	1.9	1.8	3.0	3.0
1-3 year	2.5	1.9	1.8	3.5	3.5
Breeding	2.5	1.9	2.2		
Breeding + work	2.5	2.15	2.2		
Others	2.0	1.8	2		
Age	Female Crossbred	Female Indigenous	Female Buffalo	Female Sheep	Female Goat
0-1 year	2.1	2.0	2.0	3.0	3.0
1-3 year	2.65	2.0	2.2	3.5	3.5
Milking	3.0	2.2	2.8		
Dry	2.0	2.0	2.5		
Heifers	2.0	2.0	2.5		
Others	1.8	1.8	2.0		

APPENDIX-IV**SELECTION OF HOUSEHOLDS IN THE STUDY AREA**

Farming System / Herd size category	Small (1-2)	Medium (3-4)	Large (5 and above)	Overall
(A) Crop+ Dairy	24 (94)	16 (63)	12 (47)	52 (204)
(B) crop+ dairy+ovine	28 (110)	19 (75)	10 (39)	57 (244)
(C) Others	4 (15)	4 (16)	3 (12)	11 (43)
Dairy+ Cameline				2 (8)
Crop+ dairy+ ovine+ cameline				2 (7)
Dairy				4 (15)
Dairy+ ovine				3 (13)
Total	56 (219)	39 (153)	25 (98)	120 (471)

Figures in parenthesis are total number of households enumerated in respective category

Emission Factor

The following equation is used to estimate the annual emission per animal.

$$\text{Emissions (kg/year)} = \frac{\text{Intake (MJ/day)} \times Y_M \times 365 \text{ (days)/year}}{55.65 \text{ MJ/Kg of methane}}$$

Where,

Intake = Gross energy intake from feed in Mega Joules/day

Y_M = Percentage of gross energy converted into methane

55.65 MJ/Kg of methane = Gross energy of Methane

The feed intake on fresh matter basis is expressed in terms of gross energy intakes are calculated in the following steps.

Step I. Conversion of feed intake on fresh matter basis into dry matter intake (DMI):

The average daily feed intakes on fresh matter basis, was converted into dry matter based on the percentage dry matter in the feeds (Ranjhan, 1991).

Step II. Conversion of dry matter intake into total gross energy in kilocalories:

Gross energy intake was calculated from dry matter intake as follows:

The gross energy of various types of feeds is calculated by the equation:

$$\text{G.E. (Kcal/g)} = (\text{CF} + \text{NFE}) 4.15 + (\text{CP} \times 5.65) + \text{EE} \times 9.40$$

Where

CF - Percentage of crude fibre expressed in dry matter basis.

NFE - Percentage of nutrient free extract expressed in dry matter basis

CP - Percentage of crude protein expressed in dry matter basis

EE - Percentage of other extract expressed in dry matter basis

(Banerjee, 1998)

The percentage of CF, NFE, CP and EE for different Indian feed types is obtained from the composition and nutritive value of feeds. (Sen, *et al*, 1978; Ranjhan, 1991).

Step III. Conversion of feed energy intake from kilocalories to mega joules:

A conversion factor of 4.184 was multiplied with the total gross energy intake in kcal and divided by 1000 to express the energy intake of feeds in terms of Mega joules (MJ).

Methane conversion factor (Y_M):

For the methane conversion factor (Y_M) the following equation is used:

$$Y_M = 1.30 + (0.112 \times D) + L (2.37 - 0.05D)$$

Where

Y_M is the methane yield in megaloules/100 mega joules of gross energy feed intake,

D is the digestibility of feedstock used and L is the level of feeding expressed as multiples of the energy levels needed for maintenance

Blaxter and Clapperton (1965)

APPENDIX-VIII**TOTAL OUTPUT, TOTAL INPUT AND TFP INDICES OF LIVESTOCK SECTOR IN RAJASTHAN AT CURRENT PRICES**

Years	Total Output Index	Total Input Index	TFP Index
1960-61	100.0	100.0	100.0
1961-62	107.2	114.2	93.9
1962-63	113.6	127.8	88.9
1963-64	130.4	135.3	96.4
1964-65	135.3	156.9	86.2
1965-66	135.1	158.1	85.4
1966-67	139.8	171.5	81.5
1967-68	152.3	204.5	74.5
1968-69	156.8	171.1	91.7
1969-70	166.9	177.3	94.1
1970-71	186.6	246.7	75.6
1971-72	196.0	237.4	82.5
1972-73	217.1	260.5	83.3
1973-74	259.0	315.5	82.1
1974-75	293.7	321.4	91.4
1975-76	333.2	352.2	94.6
1976-77	365.8	365.3	100.2
1977-78	405.1	413.4	98.0
1978-79	429.3	441.7	97.2
1979-80	460.8	450.1	102.4
1980-81	571.7	511.0	111.9
1981-82	667.6	571.4	116.8
1982-83	728.4	616.2	118.2
1983-84	777.1	602.9	128.9
1984-85	892.5	639.0	139.7
1985-86	989.7	839.8	117.8
1986-87	1070.9	906.0	118.2
1987-88	1134.1	940.7	120.6
1988-89	1258.5	1198.4	105.0
1989-90	1414.1	1058.3	133.6
1990-91	1449.9	1185.7	122.3
1991-92	1691.0	1207.1	140.1
1992-93	1801.7	1430.7	125.9
1993-94	2336.9	1398.1	167.1
1994-95	2645.1	1711.1	154.6
1995-96	3115.8	1914.0	162.8
1996-97	3454.5	2153.8	160.4
1997-98	3676.2	2459.3	149.5
1998-99	4783.1	2682.1	178.3
1999-00	5178.1	2805.9	184.5
2000-01	5581.6	3005.1	185.7
2001-02	5910.3	3185.3	185.5
2002-03	6088.6	2747.6	221.6
2003-04	6802.3	4047.8	168.1
2004-05	7058.9	4121.1	171.3

APPENDIX-IXa

**RANK CORRELATION COEFFICIENT AMONG SLPI* AND ITS DIMENSIONS
IN ALL DISTRICTS**

Districts	Economic Efficiency Index	Social Equity Index	Ecological Security Index	SLPI*
Economic efficiency index	1.000			
Social equity index	0.412*	1.000		
Ecological security index	-0.360*	-0.122	1.000	
SLPI*	0.718**	0.396*	0.239	1.000

** $P \leq 0.01$; * $P \leq 0.05$

APPENDIX-IXb

**RANK CORRELATION COEFFICIENT AMONG SLPI* AND ITS DIMENSIONS IN 15
LOW SLPI* DISTRICTS**

Districts	Economic Efficiency Index	Social Equity Index	Ecological Security Index	SLPI*
Economic efficiency index	1.000			
Social equity index	0.486	1.000		
Ecological security index	-0.900**	0.418	1.000	
SLPI*	0.661**	-0.157	-0.432	1.000

** $P \leq 0.01$; * $P \leq 0.05$

APPENDIX-IXc

**RANK CORRELATION COEFFICIENT AMONG SLPI* AND ITS DIMENSIONS IN 17
MODERATE SLPI* DISTRICTS**

Districts	Economic Efficiency Index	Social Equity Index	Ecological Security Index	SLPI*
Economic efficiency index	1.000			
Social equity index	0.485*	1.000		
Ecological security index	-0.434	-0.632**	1.000	
SLPI*	0.309	0.054	0.556*	1.000

** $P \leq 0.01$; * $P \leq 0.05$

APPENDIX-XIIa

AVERAGE NUMBER OF PERSONS SHARING WORK IN DIARY ACTIVITIES

S. No.	Activities engaged in dairy	Herd size categories			
		Small	Medium	Large	Over all
1.	Cleaning shed and animals	2	2	3	2
2.	Bringing fodder	2	2	3	2
3.	Giving water	2	2	3	2
4.	Chaff cutting	2	2	3	2
5.	Feeding fodder	2	2	3	2
6.	Grazing	2	2	2	2
7.	Milking	1	1	2	1

Figures are rounded off to zero decimal.

APPENDIX-XIIB

DISTRIBUTION OF HOUSEHOLDS BASED ON THE RANGE OF COMPONENTS OF DRUDGERY OF WORK

Variables / Categories	Small (N=56)	Medium (N=39)	Large (N=25)	Overall (N=120)
(A) Index of Work Sharing				
Low (<49.59)	42 (75.00)	18 (46.15)	6 (24.00)	66 (55.00)
Moderate (49.59 to 62.45)	14 (25.00)	16 (41.03)	9 (36.00)	39 (32.50)
High (>62.45)	-	5 (12.82)	10 (40.00)	15 (12.50)
Range	36.73 to 58.07	39.36 to 75.31	41.79 to 74.65	36.73 to 75.31
C.V	11.94	15.40	15.69	17.12
Geometric mean	44.92	50.71	56.95	49.10
(B) Weight carried manually (in Kg. /Km.) by workers				
Light weight (<12.5 Kg.)	27 (48.21)	16 (41.03)	10 (40.00)	53 (44.17)
Medium Weight (12.5-25 Kg.)	20 (35.71)	14 (35.90)	9 (36.00)	43 (35.83)
Heavy Weight (>25 Kg)	9 (16.07)	9 (23.08)	6 (24.00)	24 (20.00)
Minimum	0.50	2.31	2.99	0.50
Maximum	40.00	40.50	38.67	40.50
Mean	14.85	17.50	16.45	16.04
(C) Average no. of days off work affordable by main worker	18.43	17.54	14.24	17.27

APPENDIX-XIIIa

**AVERAGE DRY MATTER INTAKE (DMI) FOR DIFFERENT SPECIES
ACROSS SEASONS**

(Kg/day)

Species		Summer	Rainy	Winter	Overall
Local cow	Dry	6.84	7.28	7.47	7.20
	Lactating	7.87	7.98	8.83	8.23
Cross bred cow	Dry	10.76	10.67	11.43	10.95
	Lactating	11.09	11.24	12.34	11.55
Buffalo	Dry	9.97	9.26	10.65	9.96
	Lactating	11.05	11.11	11.74	11.30

APPENDIX-XIIIb

METHANE EMISSION FACTOR FOR DIFFERENT SPECIES

(Kg/Year)

Species		Summer	Rainy	Winter	Overall
Local cow	Dry	43.35	45.86	47.50	45.57
	Lactation	50.50	50.68	56.71	52.63
Cross Bred cow	Dry	68.17	67.21	72.98	69.45
	Lactating	71.35	71.49	80.31	74.38
Buffalo	Dry	63.59	58.42	68.22	63.41
	Lactating	70.88	70.56	75.82	72.42

APPENDIX-XIVa**PERCENTAGE DISTRIBUTION OF HOUSEHOLDS BASED ON ADOPTION OF SELECTED BREEDING PRACTICES**

(A) Breeding Practices		Small	Medium	Large	Overall
1. Method of service					
Cow [@]	Natural	80.00	50.00	16.67	58.06
	AI	20.00	50.00	83.00	41.94
Buffalo	Natural	98.15	92.31	100.00	96.61
	AI	1.85	2.56	-	1.695
	Both	-	5.13	-	1.695
2. System of mating					
Cow	Indiscriminate	73.33	30.00	16.67	48.39
	Planned	26.67	70.00	83.33	51.61
Buffalo	Indiscriminate	38.89	7.69	4.00	21.19
	Planned	61.11	92.31	96.00	78.81
3 Phenotype of bull used for natural services					
	Scrub Bull	43.64	21.05	8.33	29.06
	Specific breed bull	56.36	78.95	91.67	70.94
(B) Index of breeding practices followed by farmers					
	Minimum	34.79	37.55	41.22	34.79
	maximum	64.06	68.07	65.40	68.07
	Geometric mean	48.16	52.27	55.47	50.94

@ In crossbred cow only AI was practiced.

APPENDIX-XIVb**AVAILABILITY OF LIVESTOCK INFRASTRUCTURE FACILITIES VILLAGES**

Livestock infrastructure facilities	Percentage of sample villages in which facilities are available
AI center	1/4
Trained inseminator	1/4
Liquid Nitrogen Canes	0
Quality semen	1/4
Availability of doctor	1/4
Availability of Medicine	0
Availability of Bull	1/4
Breed of Panchayat bull	Available in only one village only Cow- Non-descriptive Buffalo - Murah

APPENDIX-XIVc

OTHER BREEDING PRACTICES FOLLOWED BY FARMERS

Sl. No	Breeding Practices	Description
1	Castration of male calves	21.43 % non adopters
2	Scientific Method of castration	63.64 % non adopters
3	Pregnancy diagnosis done	77.50 % non adopters
4	Source of AI	66.67 Private
5	Gap between heat detection and insemination	35.83 before 12 hours
6	Case of repeat breeding	14.17
7	Case of Abortion	5.83

APPENDIX-I

AGRO-CLIMATIC REGIONS/SUB REGIONS OF PLANNING COMMISSION WITH CORRESPONDING NARP ZONES IN RAJASTHAN

NARP Zones	Districts Falling	Planning commission zones/sub-zones		Districts falling
		Zones	Sub-zones	
Irrigated North-Western Plain (IB)	Ganganagar and Hanumangarh	Trans Gangetic Plain Region	Scarce rainfall arid zone.	Ganganagar and Hanumangarh
Semi-Arid Eastern Plain (IIIA)	Ajmer, Dausa, Jaipur and Tonk	Central plateau and hill region	Semi arid eastern plain	Ajmer, Dausa, Jaipur and Tonk
Flood Prone Eastern Plain (IIIB)	Alwar, Bharatpur, Dholpur, Karauli and Swai Madhopur ¹		Flood prone eastern plain	Alwar, Bharatpur, Dholpur, Karauli and Swai Madhopur
Southern Plain and Aravali Hills (IVA)	Bhilwara, Chittoregarh ² , Rajsamand and Udaipur ³		Southern Plain and Aravali Hills	Bhilwara, Chittoregarh, Rajsamand and Udaipur
Humid south eastern plain (V)	Bundi, Kota, Jhalawar, Baran and Swai Madhopur ¹		South eastern plain	Bubdi, Kota, and Baran
Humid southern plain (IVB)	Dungarpur, Banswara, Chittorgarh ² and Udaipur ³		Southern plain	Dungarpur and Banswara
Transitional plain of Luni Basin (IIB)	Pali, Sirohi, Jodhpur ⁴ and Jalore		Transitional plain	Pali and Sirohi
Transitional plain of inland drainage (IIA)	Nagaur, Sikar, Churu ⁵ and Jhunjhunu		Western dry region	Western dry region
Arid Western Plain (IA)	Barmer and Jodhpur ⁴			
Hyper arid partially irrigated western plain (IC)	Bikaner Jaisalmer, Jodhpur ⁴ and Churu ⁵	Western plateau and hill region	Plateau zone north	Jhalawar

¹ 58.31% (291233 ha out of 499424 ha) of the area of Sawai Madhopur district falls in Flood Prone Eastern Plain and therefore included in this zone.

² 67.96% (703918 ha out of 1035704 ha) of the area of Chittorgarh district falls in zone IVA and therefore included in this zone.

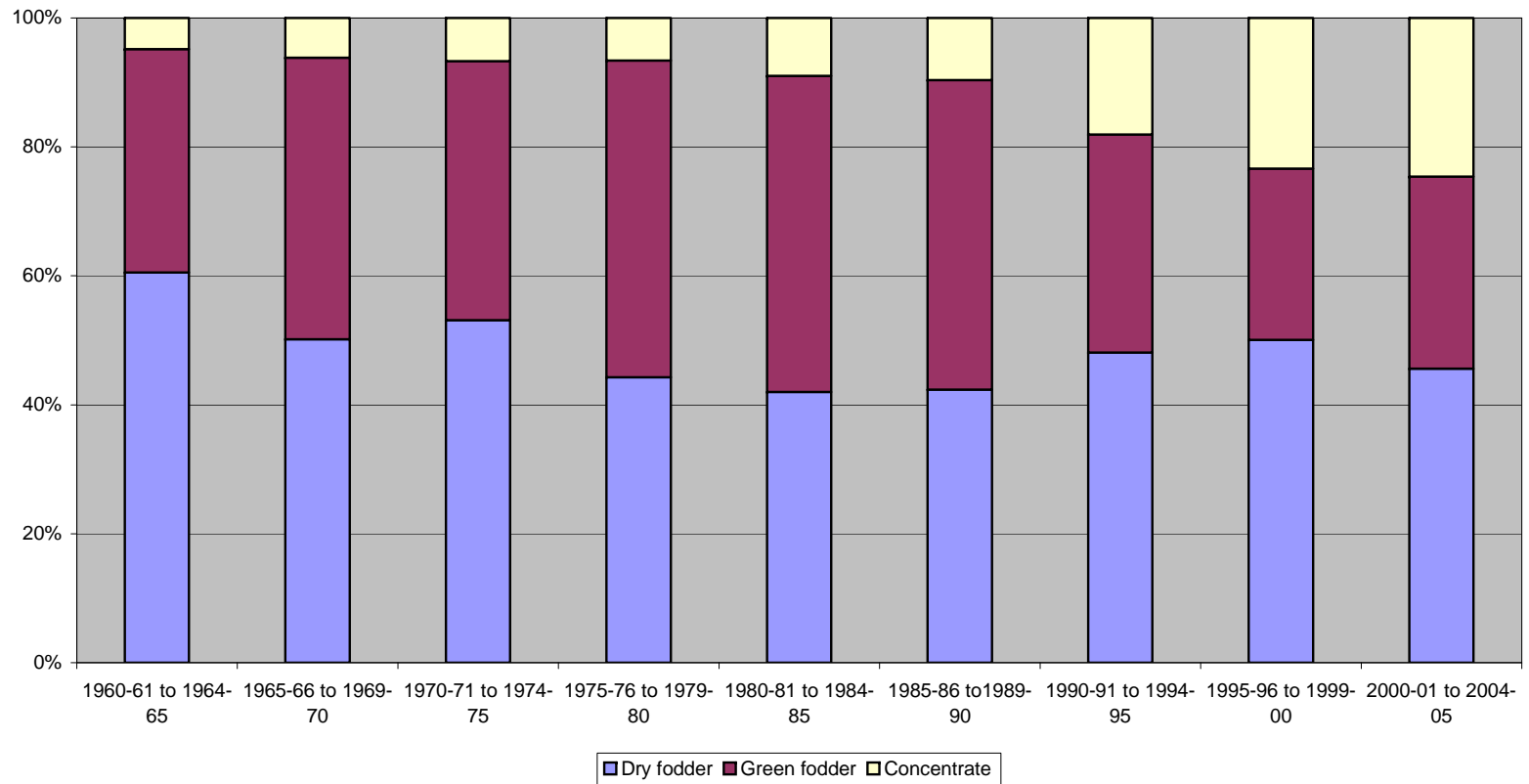
³ 65.80% (962122 ha out of 1462109 ha) of the area of Udaipur district falls in zone IVA and therefore included in this zone.

⁴ 84.57% (106319 ha out of 125724 ha) of the area of Jodhpur district falls in zone IA and therefore included in this zone.

⁵ 60% (824626 ha out of 1385889 ha) of the area of Churu district falls in zone IC and therefore included in this zone.

APPENDIX-VII

PERCENTAGE COMPOSITION OF LIVESTOCK FEED IN RAJASTHAN (QUINQUENNIAL AVERAGE)



APPENDIX-Xa

INDICATOR-WISE STATUS OF DISTRICTS ACCORDING TO SELECTED INDICATORS OF LIVESTOCK PRODUCTION

Districts	Economic Efficiency Index						Social Equity Index						Ecological Security Index			
	Livestock productivity	Rank	Labour Productivity	Rank	Calories availability	Rank	Female literacy	Rank	Infrastructure for livestock	Rank	CGR of CPRs	Rank	Surplus population	Rank	Ratio of pas. & graz. land to NSA	Rank
Low SLPI* (<0.3) districts																
DUNGARPUR	0.000	32	0.022	31	0.120	31	0.109	30	1.000	1	0.530	23	0.221	26	0.378	6
BANSWARA	0.101	28	0.055	29	0.261	28	0.010	31	0.624	5	0.525	25	0.187	31	0.249	11
CHITTORGARH	0.049	29	0.041	30	0.281	25	0.265	25	0.351	14	0.825	3	0.207	28	0.315	8
BAREN	0.124	27	0.083	28	0.193	29	0.434	17	0.216	23	0.585	12	0.301	18	0.427	4
S. MADHOPUR	0.314	20	0.185	25	0.267	26	0.235	26	0.329	16	0.080	31	0.302	17	0.196	13
UDAIPUR	0.039	30	0.163	27	0.189	30	0.480	13	0.419	12	0.534	22	0.000	32	1.000	1
JALORE	0.489	13	0.340	18	1.000	1	0.000	32	0.209	24	0.551	21	0.302	16	0.039	27
TONK	0.534	11	0.379	16	0.566	15	0.141	28	0.257	22	0.468	30	0.294	20	0.067	24
NAGAU	0.371	17	0.278	21	0.308	24	0.383	18	0.185	26	0.554	20	0.364	7	0.026	30
JHALAWAR	0.253	23	0.166	26	0.311	23	0.381	19	0.278	20	0.588	11	0.249	23	0.260	9
BHARATPUR	0.574	10	0.371	17	0.888	5	0.492	10	0.764	2	0.511	26	0.249	22	0.035	28
KOTA	0.311	21	0.334	19	0.000	32	1.000	1	0.327	17	0.000	32	0.315	12	0.255	10
BHILWARA	0.222	26	0.219	24	0.401	20	0.176	27	0.457	10	0.614	9	0.212	27	0.243	12
BARMER	0.232	25	0.259	22	0.384	21	0.486	12	0.051	31	0.569	17	0.407	6	0.067	23
PALI	0.379	16	0.532	8	0.557	16	0.272	24	0.208	25	0.574	16	0.224	25	0.151	16

Contd....

Contd....(Appendix-Xa)

Districts	Economic Efficiency Index						Social Equity Index						Ecological Security Index			
	Livestock productivity	Rank	Labour Productivity	Rank	Calories availability	Rank	Female literacy	Rank	Infrastructure for livestock	Rank	CGR of CPRs	Rank	Surplus population	Rank	Ratio of pas. & graz. land to NSA	Rank
Moderate SLPI* (0.3-0.5) districts																
ALWAR	0.664	6	0.328	20	0.981	4	0.487	11	0.520	9	1.000	1	0.202	29	0.087	21
JODHPUR	0.593	8	0.513	9	0.323	22	0.345	20	0.112	29	0.582	13	0.358	8	0.054	25
JAISALMER	0.011	31	0.640	4	0.484	18	0.140	29	0.000	32	0.578	15	0.613	4	0.167	14
JAIPUR	1.000	1	1.000	1	0.573	14	0.850	4	0.548	8	0.502	28	0.200	30	0.107	18
CHURU	0.520	12	0.000	32	0.265	27	0.781	5	0.114	28	0.507	27	0.698	2	0.009	31
BUNDI	0.277	22	0.242	23	0.505	17	0.303	22	0.290	19	0.595	10	0.311	13	0.330	7
AJMER	0.793	4	0.774	3	0.628	12	0.640	8	0.331	15	0.640	7	0.225	24	0.156	15
SIKAR	0.488	14	0.416	14	0.591	13	0.865	3	0.636	4	0.736	5	0.308	15	0.087	20
DHOLPUR	0.433	15	0.441	12	0.725	8	0.440	16	0.436	11	0.766	4	0.316	11	0.134	17
DAUSA	0.857	3	0.563	6	0.990	3	0.463	14	0.598	7	0.493	29	0.311	14	0.102	19
JHUNJHUNU	0.723	5	0.405	15	0.657	11	0.966	2	0.600	6	0.559	19	0.356	9	0.085	22
SIROHI	0.250	24	0.485	10	0.445	19	0.292	23	0.371	13	0.581	14	0.325	10	0.653	2
RAJSAMAND	0.358	19	0.554	7	0.692	10	0.307	21	0.729	3	0.567	18	0.265	21	0.421	5
GANGANAGAR	0.936	2	0.815	2	0.840	6	0.746	7	0.267	21	0.529	24	0.554	5	0.032	29
BIKANER	0.358	18	0.604	5	0.723	9	0.445	15	0.056	30	0.675	6	1.000	1	0.049	26
KARALI	0.590	9	0.440	13	0.819	7	0.531	9	0.310	18	0.619	8	0.295	19	0.527	3
HANUMANGARH	0.658	7	0.464	11	0.991	2	0.747	6	0.175	27	0.870	2	0.675	3	0.000	32
Mean	0.422		0.379		0.530		0.444		.368		.572		.339		.210	
C.V	63.9		63.1		52.9		60.10		62.8		31.8		55.3		103.4	

APPENDIX-Xb

RANK CORRELATION COEFFICIENT AMONG SELECTED INDICATORS OF SLPI

Districts	Livestock productivity	Labour Productivity	Calories availability	Female literacy	Infrastructure for livestock	CGR of CPRs	Surplus population	Ratio of pasture & grazing land to NSA
Livestock productivity	1.000							
Labour Productivity	0.591**	1.000						
Calories availability	0.700**	0.642**	1.000					
Female literacy	0.577**	0.271	0.237	1.000				
Infrastructure for livestock	0.050	-0.099	0.072	0.071	1.000			
CGR of CPRs	-0.054	0.088	0.283	0.045	-0.121	1.000		
Surplus population	0.170	0.286	0.170	0.259	-0.614**	0.040	1.000	
Ratio of pasture & grazing land to NSA	-0.582**	-0.257	-0.446*	-0.305	0.361*	0.090	-0.519**	1.000

**P≤0.01; *P≤0.05

APPENDIX-XI

AVERAGE NET MAINTENANCE COST FOR MILCH ANIMALS ACROSS HERD SIZE CATEGORIES

(Rs./ milch animal/day)

S. No.	Components/ Categories	Local cow				Cross-bred cow				Buffalo			
		Small	Medium	Large	Overall	Small	Medium	Large	Overall	Small	Medium	Large	Overall
(A)	Total fixed cost	3.73 (9.30)	3.55 (9.50)	3.67 (8.57)	3.66 (9.20)	7.70 (11.37)	6.15 (10.28)	8.30 (12.16)	7.32 (11.22)	6.59 (11.25)	6.77 (11.66)	6.7 (11.75)	6.69 (11.48)
(i)	Deprecation on fixed assets	2.71 (6.76)	2.40 (6.42)	2.46 (5.74)	2.56 (6.43)	4.92 (7.26)	3.79 (6.33)	4.93 (7.22)	4.55 (6.98)	4.26 (7.27)	4.24 (7.31)	4.17 (7.21)	4.23 (7.26)
(ii)	Interest on fixed assets	1.02 (2.54)	1.15 (3.08)	1.21 (2.83)	1.10 (2.77)	2.78 (4.10)	2.36 (3.94)	3.37 (4.94)	2.77 (4.24)	2.33 (3.98)	2.53 (4.36)	2.62 (4.53)	2.46 (4.22)
(B)	Total variable cost	36.36 (90.70)	33.81 (90.50)	39.16 (91.43)	36.11 (90.80)	60.03 (88.63)	53.68 (89.72)	59.95 (87.84)	57.95 (88.78)	52.01 (88.75)	51.27 (88.34)	51.01 (88.25)	51.56 (88.52)
(i)	Feed cost	29.07 (72.51)	27.32 (73.13)	33.24 (77.61)	29.37 (73.84)	51.21 (75.61)	45.08 (75.35)	50.85 (74.51)	49.14 (75.29)	41.37 (70.60)	41.33 (71.21)	41.47 (71.75)	41.38 (71.04)
(ii)	Labour cost* (Family labour)	6.84 (17.06)	6.13 (16.41)	5.75 (13.43)	6.38 (16.05)	8.46 (12.49)	8.18 (13.67)	8.69 (12.73)	8.42 (12.90)	9.93 (16.95)	9.37 (16.14)	9.06 (15.67)	9.57 (16.42)
(iii)	Vet. & Misc. Exp.	0.45 (1.12)	0.36 (0.96)	0.17 (0.40)	0.36 (0.91)	0.36 (0.53)	0.42 (0.70)	0.41 (0.60)	0.39 (0.60)	0.71 (1.21)	0.57 (0.98)	0.48 (0.83)	0.62 (1.06)
(C)	Gross cost (A+B)	40.09 (100)	37.36 (100)	42.83 (100)	39.77 (100)	67.7 3(100)	59.83 (100)	68.25 (100)	65.27 (100)	58.60 (100)	58.04 (100)	57.80 (100)	58.25 (11.75)
(D)	Imputed value of dung	1.30	1.39	1.42	1.35	2.38	2.05	2.40	2.28	2.12	2.17	2.12	2.14
(E)	Net cost (C-D)	38.79	35.97	41.41	38.42	65.35	57.78	65.85	62.99	56.48	55.87	55.68	56.12
(F)	Average milk yield (lit)	3.21	3.02	3.94	3.30	6.42	6.50	7.90	6.75	4.43	4.62	4.67	4.54
(G)	Net cost of milk production/lit (E/F)	12.08	11.91	10.51	11.64	10.18	8.89	8.34	9.33	12.75	12.09	11.92	12.36

Figures in parenthesis are percentage of gross cost

* The entire labour was family labour