Economic and Social Commission for Asia and the Pacific

CGPRT Centre WORKING PAPER No. 64

Prospects of Feed Crops in India: the Role of CGPRT Crops

P.S. Pathak

United Nations

The CGPRT Centre

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In co-operation with ESCAP member countries, the Centre will initiate and promote research, training and dissemination of information on socio-economic and related aspects of CGPRT crops in Asia and the Pacific. In its activities, the Centre aims to serve the needs of institutions concerned with planning, research, extension and development in relation to CGPRT crop production, marketing and use.

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Prospects of Feed Crops in India: the Role of CGPRT Crops

“CGPRT Centre Works Towards Reducing Poverty Through Enhancing Sustainable Agriculture in Asia and the Pacific Region”

WORKING PAPER 64

Prospects of Feed Crops in India: the Role of CGPRT Crops

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Humid Tropics of Asia and the Pacific

Table of Contents

List of Tables

List of Figures

Foreword

Coarse grains, pulses, root and tuber (CGPRT) crops are a very important component of the farming system in Asia and the Pacific region, particularly in the marginal areas where economically, ecologically and socially less favorable conditions prevail, and many farmers' activities and lives rely on CGPRT crops. Therefore, it is crucial to promote the sustainable production of CGPRT crops and to expand the income generation opportunities through expanding market opportunities of CGPRT crops.

CGPRT crops are versatile crops and they can provide an extraordinary range of end uses, not only as foods for direct human consumption but also as materials for a diverse range of end products, including industrial uses. Feed is one of the alternative end products of CGPRT crops.

In developing countries, there has been a dramatic rise in the consumption of animal origin food products. It was a result of demand changes caused by changes in the diets of billions of people in the region, through population growth, urbanization, and income growth in these countries.

As animal-product demand increases, feed grain utilization also increases. Animal feeds are dominated by coarse grains, pulses, root and tuber crops or the products of these CGPRT crops. Therefore, this provides an expansion of market opportunity for CGPRT crops.

The development of animal husbandry and demands for feed vary greatly from country to country. Therefore, we need to analyze them comparing among countries within the region. Responding to this need, the CGPRT Centre has implemented a research project, "Prospects of Feed Crops in South Asia", in collaboration with partners from four countries: India, Nepal, Pakistan and Sri Lanka.

It is my pleasure to publish **Prospects of Feed Crops in India: the Role of CGPRT Crops** as one of the results of the project. This volume covers topics such as historical overviews of animal industry, agricultural policies, trading policies and prospects of feed demand and supply in India.

I thank Dr. Prem S. Pathak for his earnest and fruitful work. This study could only be accomplished with the continuous support from the Indian Grassland and Fodder Research Institute, India. Mr. S.S.E Ranawana, professor of Wayamba University, Sri Lanka, and Dr. Budiman Hutabarat provided useful comments and guidance at various stages of the study as the regional advisor and the programme leader, respectively. I also thank Mr. Matthew Burrows for his editing services throughout the publication of the report. Finally, I would like to express my sincere appreciation to the Government of Japan for its support in funding the project.

June 2003

Nobuyoshi Maeno
Director
CGPRT Centre

Preface

Animal husbandry is the backbone of Indian agriculture. It provides livelihood opportunities to the farmers (more than 70 per cent of the population) who depend on mixed farming. Animals not only contribute to household nutrition and income, they provide draught power and organic manure, as well as many other products. Currently, animal production is being emphasized to meet the nutritional demands of the increasing population of human beings. It is also true that improved economic standards encourage higher demand for livestock products. Intensive production is being targeted for the enormous livestock population in the country to meet the demands. Proper feed management is of paramount importance to obtain the desired goal of animal production where coarse cereals play a major role. Since most livestock production comes from small and medium households, the feeding system also depends upon domestic availability. The estimated requirement of feeds for livestock is short by 64 per cent. To meet this gap and analyze the scenario, the CGPRT Centre, Bogor, Indonesia proposed a research project on "Prospects of Feed Crops in South Asia" under which this study has been attempted. I am sure this report will provide sufficient back up for encouraging research on production of coarse cereals to meet the demands in the country and also balancing its management.

P.S. Pathak

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P.S.Pathak

Executive Summary

The CGPRT sponsored project on "Prospects of Feed Crops in South Asia (FEED)" was attempted during the year 2001-02. The study was initiated to understand the demand-supply gap of various feed crops and identify measures to bridge it. Several models were introduced and discussed in a meeting held in Bogor (Indonesia) in September 2001 for determining the demand and supply of different feed crops. These are presented in this study.

For this study, data was collected from the Department of Animal Husbandry and Dairying, Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India, New Delhi. Data was also collected from other sources to understand the behaviour of exports and also the uses of animal feeds. Information from the Director and scientists at the National Centre for Agricultural Economics and Policy Research, New Delhi and Agricultural Universities in the country has been used in the study. Discussions were also held at the International Crop Research Institute for Semi-Arid Tropics, Patencheru, Hyderabad. The data was processed and models were made for crops including, maize, sorghum, pearl millet, barley and ragi. Prediction through the models was also incorporated to understand the behaviour of demand and supply.

Population growth in cattle shows a negative growth trend while the maximum increase is shown in poultry (2.786 per cent per annum). During the past 2 decades, per capita consumption has increased at a rate of 7.8 per cent in chicken and 6.59 per cent in eggs. It is found that in the next 20 years, the demand for livestock products will grow at 5.75 per cent for which improved feeding systems will be imperative. Feed manufacturers have to be up scaled to meet the challenge. The demand for feed has been calculated (based on nutritional needs) to be 114.35 million tons for 2002, which shall increase at a rate of 2.62 per cent per annum. Against the demand, the supply, tested by four models, may reach 67.55 mt, which is short by 40.93 per cent. This shortfall could be at least partly bridged considering that small and medium farmers in the unorganized sector, including the 35 per cent of poultry, practice large amounts of dairying in India.

It is found that most of the coarse cereals are facing decline in cultivated area and also productivity. In the case of maize, the annual growth rate of production and area shows a slow increase, while in all other crops there is a decline. It appears that crops like maize and sorghum have the potential to meet the demand if sufficient emphasis is given to further improve the productivity of the farming systems and R&D activities. Since livestock production activities in India are mostly at the household level of small and marginal farmers, feeding systems are dependent upon the indigenous practices. Only about 65 per cent of poultry and less than 10 per cent of dairying are in the organized sector for which feeding standards require standard feeds.

Finally, it is concluded that depending on the demand, productivity and the production scenario, it is possible to bridge the gap between demand and supply. Accelerated production activities and marketing policies should control the market so that the farmers receive better prices for their production and upgrade their farming enterprize.

1. Introduction

1.1 Background and justification

Global trends in animal production indicate a rapid and massive increase in the consumption of animal products. It is predicted for 2020 that meat and milk consumption will grow at 2.8 and 3.3 per cent per annum respectively in less developed countries. Meat consumption in least developed countries will increase from 88 to 188 million tons and developing countries will require 223 million tons more milk. In terms of value, livestock products will equal or exceed products from crops.

India, with only 2.0 per cent of the worlds land area has 16 per cent of the cattle, 54 per cent of the buffalo, 5 per cent of the sheep and 21 per cent of the goats. India has a livestock population of 717.5 million, which has grown at a rate of 2.04 per cent annually (between 1987-92) (Tables 1.1 and 1.2). The annual growth rate has been declining ever since 1992 with mean growth rate of 1.23 per cent between 1992-1997. Due to land use changes and livelihood demands there have been wide variations in the growth trends between livestock species. Annual growth rates for different species of livestock have been declining except sheep and poultry (Table 1.2) with a negative growth rate for cattle. Maximum growth is recorded in poultry followed by sheep.

Table 1.1 Livestock population – projected estimates* (in million)

Year	Cattle	Buffalo	Sheep	Goat	Pig	Poultry	Equine	Camel	Total
2002	201.0	97.0	65.0	122.1	14.8	396.3	0.4	1.3	897.9
2003	200.8	98.6	66.6	123.2	15.1	406.1	0.4	1.3	912.0
2004	200.7	100.1	68.2	124.2	15.5	416.2	0.4	1.3	926.5
2005	200.5	101.7	69.8	125.3	15.8	426.6	0.4	1.3	941.3
2006	200.3	103.3	71.5	126.4	16.1	437.2	0.4	1.3	956.4
2007	200.2	105.0	73.2	127.4	16.4	448.1	0.3	1.3	971.9
2008	200.0	106.7	75.0	128.5	16.8	459.2	0.3	1.3	987.8
2009	199.8	108.4	76.8	129.6	17.1	470.6	0.3	1.3	1,004.0
2010	199.6	110.1	78.6	130.7	17.5	482.4	0.3	1.3	1,020.5
2011	199.5	111.8	80.5	131.9	17.8	494.4	0.3	1.3	1,037.5
2012	199.3	113.6	82.5	133.0	18.2	506.7	0.3	1.3	1,054.9

(* Estimates based on livestock population data from 1950-1992 and provisional for 1997 collected from the Livestock Census, Department of Animal Husbandry and Dairy, Ministry of Agriculture, New Delhi. The figures were projected to 2012 using growth trends).

Table 1.2 Growth trends in livestock population (% annual growth)*

	Population (million)			% annual growth rate		
	1987	1992	1997	1987-1992	1992-1997	1987-1997
Cattle	199.7	204.6	198	0.491	-0.645	-0.085
Buffalo	76.0	84.2	89	2.158	1.140	1.711
Sheep	45.7	50.8	58	2.232	2.835	2.691
Goat	110.2	115.3	120	0.926	0.815	0.889
Pig	10.6	12.8	13	4.151	0.312	2.264
Poultry	275.3	307.1	352	2.310	2.924	2.786
Total	717.5	774.8	830	2.04	1.23	1.71

*Based on 1987, 1992, 1997 population observations using growth trends.

Source: Estimates based on livestock population data from 1950-1992 and provisional for 1997 collected from the Livestock Census, Department of Animal Husbandry and Dairy, Ministry of Agriculture, New Delhi. The figures were projected to 2012 using growth trends

The livestock sector plays an important role in the National Economy and in the socio-economic development of the country, supplementing family income and generating gainful self-employment in the rural sector. Livestock contributed 6.7 per cent to the National Gross Domestic Product (GDP) during the year 2000-2001. The livestock sector contributes Rs 1,830,000 million to the annual revenue i.e. 32 per cent of the agricultural output, which is 27 per cent of the total GDP. It is expected to rise to 50 per cent by the year 2020. Livestock are also related to rural prosperity whereby their share in rural households ensures poverty reduction (Figure 1.1). The livestock sector also provides 70 per cent of the employment in rural areas. Therefore, this sector is designated as having the most potential of the few growth sectors of the agricultural economy. The present level of production of animal products viz., milk, meat, fibre and eggs will have to be augmented in response to growing demand from the human population, which has already crossed the 1,000 million mark (Table 1.3).

Figure 1.1 Livestock share in agricultural based livelihood and poverty relationship in India

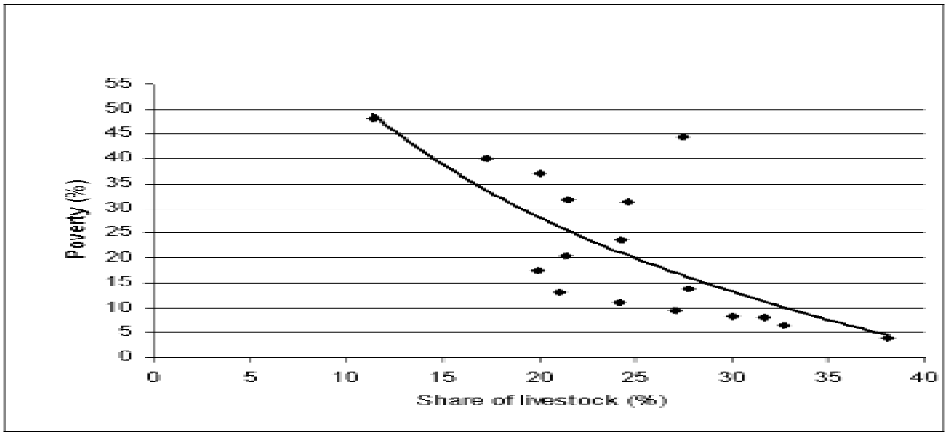


Table 1.3 Projected human population in India (in million)

Dot-ails	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Male	530.05	541.9	552.74	563.8	575.07	586.57	597.71	608.98	620.26	631.54	642.81
Female	495.04	505.65	515.77	526.1	536.6	547.33	557.55	567.97	578.39	588.81	599.23
Total	1,025.09	1,047.55	1,068.51	1,089.9	1,111.67	1,133.9	1,155.26	1,176.96	1,198.65	1,220.35	1,242.04

India has shown tremendous progress in milk production (84.456 million tons in 2000-01 against 57.96 million tons in 1992) during the past decade but per capita availability (226 g against 182 g per head respectively) has to not only increase but also has to be well within the reach of the population below the poverty line (40 per cent at present) (Table 1.4). The increase in demand has been calculated using growth trends of past records but will require further augmentation in view of the increasing economic standards of the population.

Table 1.4 Projected requirement of milk for domestic demand and export (million tons) (based on growth trends)

Demand	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Domestic	93.58	95.59	97.5	99.45	101.44	103.47	105.4	107.37	109.34	111.31	113.28
Export @ 5 per cent	4.683	4.78	4.88	4.97	5.07	5.17	5.27	5.36	5.46	5.56	5.65
Total	98.263	100.37	102.38	104.42	106.51	108.64	110.66	112.73	114.79	116.86	118.93

Table 1.5 Production, demand for and net trade of livestock products in South Asia (SA), 1990-2020 baseline scenario (1,000 mt)

Commodity/ Country	1990			2020		
	Production	Demand	Net trade	Production	Demand	Net trade
Beef SA	1,332	1,385	-53	2,821	3,807	-986
India	851	786	65	1,812	1,924	-112
Pig meat SA	372	366	6	912	1,002	-90
India	360	359	1	893	981	-88
Sheep meat SA	1,044	1,110	-66	2,588	3,185	-597
India	538	540	-2	1,203	1,398	-196
Poultry meat SA	548	539	9	1,454	2,101	-647
India	282	283	-1	886	1,086	-200
Total meat SA	3,296	3,400	-104	7,775	10,095	-2,320
India	2,031	1,968	63	4,794	5,389	-596
Eggs SA	1,475	1,475	0	4,161	4,240	-79
India	1,132	1,131	1	3,119	2,962	157

Source: IMPACT simulation results, Quoted in Rosegrant *et al*., 1995.

It is meat and egg production that is required to be up scaled to meet the increasing human needs. A study conducted by Rosegrant *et al*., 1995, shows that while India had a positive balance between the demand and supply for meat and eggs, by the year 2020 it is going to face a huge deficit in almost all of the items except egg production (Table 1.5).

The present scenario of rural poultry shows 65 per cent production from industrial poultry and only 35 per cent from the rural sector. The rural poultry sector, although ignored so far, requires little hand feeding and manages to give a handsome return with minimal night shelter. Rural consumption is 30 per cent of the total. It has the potential to generate additional income/employment and the amelioration of nutritional status.

To meet the demands of increasing numbers of livestock and also their higher productivity, feed resources have to be augmented. In animal feed supply, coarse cereals have a major role. Coarse cereals account for about half of the total cereals produced in the world. The four major coarse cereals viz., maize, barley, sorghum and pearl millet account for about 44 per cent of the total cereals. Of the total coarse cereals, maize accounts for almost three quarters and barley accounts for 15 per cent. Sorghum and millet accounts for 11 per cent. India’s production of these cereals is stagnating at around 30 million tons, which is less than 3 per cent of the world's production. The role of food grains and specifically of coarse cereals in providing balanced nutrition to livestock for ensuring higher productivity needs no emphasis. At present, the country faces a net deficit of 61.1 per cent in green fodder, 21.9 per cent in dry crop residues and 64 per cent in feeds.

This study is an attempt to examine the status of feed crops and their role in livestock production and the rural economy.

1.2 Objectives

The overall goal of this project are:

To elucidate and analyze potentials, weaknesses, opportunities, constraints and policy options for the development of feed crop farming in south Asian (India) developing countries in balance with the rapid development of the livestock and fish culture industry in Asia.

The specific objectives of this study are:

- To analyze historical dynamics and future trends of demand and supply for feed crops and evaluate their potential for developing the livestock industry.
- To evaluate potentials, weaknesses, opportunities and constraints for expanding feed crop farming in the participating countries.

- To propose possible cooperation schemes for the trade and development of feed crops / products among Asian countries.
- To formulate policy options to promote the sustainable development of feed crop farming in the participating countries.

1.3 Scope of study and commodity coverage

- The study focus is on crops (coarse grains) that are now termed as nutri-cereals used as animal feed as well as being the staple food of a large population in India. These crops are maize, sorghum, pearl millet, barley and ragi.
- Thus, this project will result in a clearer understanding of the dynamics and future trends of demand and supply of feed crop products in India.
- The potentials, weaknesses, opportunities and constraints for expanding feed crop farming in India will be clearly understood.
- It will help in formulating strategies and policy options for the development and promotion of sustainable feed crop farming options in India.
- A regional cooperation scheme between the ESCAP member countries may develop as a result of this study.

1.4 Organization of the report

In India, the major components of animal feed are maize, sorghum, pearl millet, minor millets and barley, besides broken grains of rice and wheat and also the wheat and rice bran that is derived from the processing of wheat and pulses from the mills. However, in India, their use is mainly for direct consumption mostly by the poor in the villages. Many crop species are combined as minor millets viz., Finger millet/Ragi (*Eleusine coracana*), Little millet (*Panicum miliare*), Kodo millet (*Paspalum scrobiculatum*), Foxtail millet (*Setaria italica*), Barnyard millet (*Echinochloa frumentacea*), Proso millet (*Panicum miliaceum*) and Savan millet (*Echinochloa colona*).

This report examines the current status of area, production, demand and supply of these crops and also tries to suggest measures for closing the supply and demand gap with policy recommendations. Appropriate models have been formulated to test past trends and suggest future growth of these commodities. The report is presented in nine chapters with a preface, acknowledgements and the executive summary. The chapters include Introduction, Methodological Approach, Review of the Current Status, Demand for Feed and Feed Crops, Supply of Feed and Feed Crops, Measures for Closing the Supply and Demand Gap, Conclusion and Recommendations, References cited and Appendix. The report is also supported with appropriate figures and tables.

2. Methodological Approach

2.1 Conceptual framework

2.1.1 Definition

An economic model is merely a theoretical construct or analytical framework composed of a set of assumptions from which conclusions are derived.

In this model building process, three steps are involved. In the first step, the model builder must select the variables and relationships among them that seem most pertinent to the problem to be attempted. This step produces the economic model, which contains a set of assumptions regarding the relevant variables and the relationships among them. Secondly, apply the necessary corrections to the model and derive a theoretical/logical conclusion. Thirdly, test the conclusion against the real phenomenon. If the observed conclusions do not fall in agreement with the derived data either a new hypothesis can emerge or a new conclusion is derived.

2.2 Analytical framework

Increases in livestock numbers and a growing human population in developing countries have to depend upon the land use and management options for their sustenance. Three primary sources of growth as regards to livestock are prevailing in developing countries. These are an expansion in livestock numbers; increased intensity of range and pasture utilization and better use of feed concentrates and agricultural by-products; and higher output of meat, milk or eggs per animal through improved feeding management, breeds and technologies. However, in many developing countries the lack of potential to either increase the area of grazing land or to raise its productivity will result in higher yields being an increasingly important source of growth. The area and production statistics of India are based on the crop cutting experiments laid in different agro-ecological zones of the country. Agricultural field experiments are conducted at different centres incorporating trend statistics about the area/production/import/export and consumption through sampling methodologies. Statistics on different crops gives us an idea about the supply and demand level of the crops to compete with the growing population trends. The DES (Directorate of Economics and Statistics, Ministry of Agriculture and Cooperation, Govt. of India) provides yield estimations with respect to principal crops of food grains, oilseeds, sugarcane, fibres etc., which contributes about 87 per cent of the agricultural output. These estimates of crop production are obtained by multiplication of area estimates by corresponding yield estimates.

In India, coarse cereals are a staple food for the poor and are a source of income for many farmers in arid and semi-arid regions. They provide a source of income and employment. Maize, barley, sorghum and pearl millet account for 15.61 per cent of the total cereals. Of the total coarse cereals, maize contributes 75 per cent and barley 15 per cent. Sorghum and millet contribute just 11 per cent. Per annum growth of total cereals in India was 2.61 per cent (in 1961-1999) keeping pace with the growth in population (2 per cent). Wheat and rice mainly contributed to this growth, while coarse cereals (millet - 0.46 per cent and sorghum - 0.23 per cent), except maize (2.28 per cent), have shown low growth rates and negative growth. Area under rice and wheat increased, while declining for all other coarse cereals with the exception of maize.

2.3 Model formulation

Models were formulated on the basis of growth trends observed during the last 20 year's data records (Agricultural Statistics at a Glance, 2001, Directorate of Economics and Statistics, DAC, Ministry of Agriculture, Govt. of India, 1950-51 to 2001-02). Before the formulation process it was assumed that the current trends of acreage as well as production would have a strong association with the previous year's data of both production and farm produce prices of commodities (current status is dependent on the previous year's status). The production components viz., feed, food, seed-uses etc. in maize are derived from maize production as per Singh (2001). The seed and waste estimation models were evolved on the basis of FAO statistics available for maize. For other crops except ragi, the data records of components as per FAO statistics have been used. For sorghum, components of production utilization were based on discussions with the concerned workers and have been derived as feed 39.01 per cent, seed 3 per cent, food 48.9 per cent and waste 6 per cent. Components in ragi have been derived as per the method used for maize. The following models have been formulated:

Acreage function

$Ln(A_t) = a + b\ Ln(PP\ at\ _{t-1}) + c\ Ln,(A\ _{t-1})$

Where A_t = area under production at time t^{th} year, $A(_{t-1})$ = area under production at $(_{t-1})^{th}$ year, and PP $_{t-1}$ = farm produce price of concerned crop at time $(_{t-1})^{th}$ year. (Ln stands for Log_e)

Production function

$Ln(Y_t) = a + b\ Ln(PP\ _{t-1}) + c\ Ln,(Urea\ price\ _{t-1}) + d\ Ln(Y_{t-1})$

Where Y_t = production at time t^{th} year, $Y(_{t-1})$ = production at $(_{t-1})^{th}$ year, urea price $_{t-1}$ = price of urea in the previous year, PP $_{t-1}$is the farm produce price of the crop in the previous year.

Feed estimation

$Ln(P_t\ ) = a + b\ Ln(PP\ _{t-1}) + c\ Ln,(Urea\ price\ _{t-1}) + d\ Ln(Y_{t-1})$

Where P_t = feed use at time t^{th} year, $PP(_{t-1})$ = farm produce price of the crop at $(_{t-1})^{th}$ year, Meat $_{t-1}$ and Eggs $_{t-1}$ are the meat and eggs production in the previous $(_{t-1})^{th}$ year.

Food estimation

$Ln(P_t) = a + b\ Ln(PP\ _{t-1}) + c\ Ln(Rice\_price\ _{t-1}) + d\ Ln\ (Per\ Capita\ Income\ at\ _t) + e\ Ln(Population\ at\ _t)$

Where P_t = food use at time t^{th} year, $PP(_{t-1})$ = farm produce price at $(_{t-1})^{th}$ year

Seed/processing estimation (used only for maize)

$Ln(P_t) = a + b\ Ln(A\ _{t-1}) + c\ Ln\ (yield\ at\ _{t-1}) + d\ Ln\ (PP\ _{t-1})$

Where P_t = seed use/processing at time t^{th} year, PP_{t-1} = farm produce price of the crop at $(_{t-1})^{th}$ year

For the rest of the crops the model used is:

$Ln\ (P_t) = a + b\ Ln(PP_t) + c\ Ln\ (meat\ at\ _t) + d\ Ln\ (Eggs\ at\ _t)$

Where P_t = seed-use/ processing at time t^{th} year, PP_t = farm produce price of the crop at $(t)^{th}$ year

This was carried out since there were negligible differences between the two models used for estimation. It can also be presumed that the seed/processing use depends not only upon the yield, area and farm produce price but also the prevalent use for the production of meat and eggs.

Waste estimation

Ln (P_t) = a + b Ln(PP $_{t-1}$) + c Ln(Rice_price $_{t-1}$) + d Ln (Per Capita Income at $_t$) + e Ln (Population at $_t$)

Where P_t = waste at time t^{th} year, PP($_{t-1}$)= farm produce price at ($_{t-1}$)th year

The crop-wise models evolved are as follows:

2.3.1 Maize

Area estimation

Ln(A_t) = a + b Ln(PP at $_{t-1}$) + c Ln(A $_{t-1}$)

Where A_t = area under production at time t^{th} year, A($_{t-1}$) = area under production at ($_{t-1}$)th year, and PP $_{t-1}$ = farm produce price of maize at time ($_{t-1}$)th year.

Coefficients	Estimates	t- statistics
a	1.015	2.210
b	0.085	2.707
c	0.179	0.536

R^2= 0.816, D-W statistic=2.261

The acreage estimation model in maize could explain 81.6 per cent variation in the estimated values. The significance of the D-W statistic shows the absence of serial correlation amongst the errors and the strength of the relationship. A significant contribution of maize farm produce price was observed in the estimation.

Yield estimation

Ln(Y_t) = a + b Ln(PP $_{t-1}$) + c Ln,(Urea price $_{t-1}$) + d Ln(Y_{t-1})

Where Y_t = yield at time t^{th} year, and $Y_{(t-1)}$ = yield at ($_{t-1}$)th year

Coefficients	Estimates	t- statistics
a	7.275	7.661
b	0.362	4.270
c	-0.308	-1.057
d	-0.176	-1.888

R2= 0.973, D-W statistic=2.291

The yield estimation model could explain 97.3 per cent variation in the estimation of maize yield. The significance of the D-W statistic also supports the strength of the model. Maximum contribution in the estimation comes from farm produce price of maize followed by yield of the previous year. Production estimation is derived from acreage and yield of maize.

Feed estimation

Ln (P_t) = a + b Ln(PP $_{t-1}$) + c Ln,(meat $_{t-1}$) + d Ln(Eggs$_{t-1}$)

Where P_t = feed use at time t^{th} year, and PP($_{t-1}$) = farm produce price at ($_{t-1}$)th year

Coefficients	Estimates	t- statistics
a	1.872	5.508
b	0.097	2.636
c	-0.027	-0.751
d	-0.106	-1.965

R2= 0.721, D-W statistic=2.207

The feed estimation model explains 72.10 per cent variation in the estimation. The significance of the farm produce price of maize in the previous year has been observed in the estimation. The D-W statistic value assures the non-existence of serial correlation amongst the errors.

Food estimation

$Ln(P_t) = a + b\ Ln(PP_{t-1}) + c\ Ln(Rice\_price_{t-1}) + d\ Ln\ (Per\ Capita\ Income\ at\ _t) + e\ Ln(Population\ at\ _t)$

Where P_t = food use at time t^{th} year, and $PP_{(t-1)}$ = farm produce price at $(_{t-1})^{th}$ year

Coefficients	Estimates	t- statistics
a	3.500	2.001
b	0.112	1.901
c	0.051	1.517
d	-0.038	-1.623
e	-0.460	0.314

R2= 0.782, D-W statistic=3.318

The food estimation model could explain 78.2 per cent variation in the estimated values. The D-W statistic supports the validity of the formulated model in food estimation of maize. Here also, the farm produce price of the previous year was the major factor responsible for the estimation of the food component of maize. This is followed by per capita income and rice price of the previous year.

Seed estimation

$Ln(P_t) = a + b\ Ln(PP\ at\ _t) + c\ Ln(meat\ at\ _t) + d\ Ln\ (eggs\ at\ _t)$

Where P_t = seed use at time t^{th} year, and PP_t = farm produce price of maize at $(_t)^{th}$ year

Coefficients	Estimates	t- statistics
a	13.394	1.185
b	1.274	1.585
c	-1.085	-1.421
d	-1.186	-1.013

R2= 0.329, D-W statistic=2.224

The seed estimation model of maize with respect to farm produce price, meat production and egg production explains 32.9 per cent variation in the estimation. The D-W statistic value shows the absence of serial correlation amongst the errors and the strength of the model. The major contributor in the maize seed estimation was farm produce price of maize followed by meat and egg production respectively.

Waste estimation

$Ln(P_t) = a + b\ Ln(PP_{t-1}) + c\ Ln(Rice\_price_{t-1}) + d\ Ln\ (Per\ Capita\ Income\ at\ _t) + e\ Ln(Population\ at\ _t)$

Where P_t = waste-use at time t^{th} year, and $PP_{(t-1)}$ = farm produce price at $(_{t-1})^{th}$ year

Coefficients	Estimates	t- statistics
a	-36.341	-1.547
b	0.812	0.477
c	-1.720	-1.330
d	0.311	0.667
e	5.717	1.468

R2= 0.563, D-W statistic=2.239

The waste estimation of maize with respect to farm produce price, rice price of the previous year along with per capita income and human population of the current year could explain only 56.3 per cent variation in the estimation. The D-W statistic value shows the absence of serial correlations amongst the errors and strength of the model for waste estimation of maize.

Based on the above models, projections for the future status of maize acreage and production for the coming 10 years (2002-2012) have been made (Table 2.1). The feed and food use of maize have been derived as per Singh (2001) and also the Indian Agricultural Policy (Ministry of Agriculture, Govt. of India, 2000) for coarse cereals, which indicates that 87.5 per cent is consumed as food, 5 per cent as feed for animal and poultry requirements, 5 per cent to be kept as seed source and 2.5 per cent as waste. The seed and waste estimation models have been evolved using data records of FAO statistics. Processed maize has been devised as the difference of all the components from the production levels. Column 3 of the table gives projections for maize production (supply) and column 5 to column 9 refer to demand of maize during the projection period. The acreage under maize shows a small increase and the yield potential of this crop is expected to show increases in the coming decade. Mainly the winter maize will contribute to this increase.

Table 2.1 Maize area and production projections in India

Year	Area (mha)	Production (mt)	Yield (kg/ha)	Feed (mt)	Food (mt)	Seed (mt)	Waste (mt)	Processing (mt)
2002	6.55	12.60000	1806.00	4.23954	3.01217	0.64411	0.71797	3.98621
2003	6.43	13.72127	2133.45	4.15293	2.92481	0.64150	0.74534	5.25669
2004	6.43	12.85640	1999.86	4.10761	2.87855	0.63907	0.82845	4.40271
2005	6.45	12.82250	1989.52	4.07847	2.84835	0.63678	0.92605	4.33285
2006	6.46	12.75250	1972.94	4.05781	2.82659	0.63462	0.97647	4.25700
2007	6.48	12.73637	1964.93	4.04230	2.80997	0.63258	1.04149	4.21003
2008	6.50	12.73667	1959.79	4.03020	2.79677	0.63064	1.09134	4.18772
2009	6.52	12.74971	1956.91	4.02048	2.78597	0.62880	1.11269	4.20177
2010	6.53	12.77050	1955.48	4.01251	2.77694	0.62705	1.21747	4.13652
2011	6.55	12.79651	1955.09	4.00587	2.76927	0.62537	1.29268	4.10332
2012	6.56	12.82603	1955.44	4.00025	2.76265	0.62377	1.35337	4.08598

Source: Author's calculation.

2.3.2 Pearl millet (Bajra)

Area estimation

$Ln(A_t) = a + b\ Ln(PP\ at\ _{t-1}) + c\ Ln,(A\ _{t-1})$

Where A_t = area under production at time t^{th} year, $A(_{t-1})$ = area under production at $(_{t-1})^{th}$ year, and PP_{t-1} = farm produce price of bajra at time $_{t-1}$.

Coefficients	Estimates	t- statistics
a	5.626	6.815
b	-0.272	-5.266
c	-0.796	-3.210

R2= 0.803, D-W statistic=2.640

The acreage function of bajra could explain 80.30 per cent variation in the estimated values. The D-W statistic value shows the absence of serial correlation amongst the errors. The significant contributors to the estimation were farm produce price of the previous year followed by bajra acreage of the previous year.

Production estimation

$Ln(P_t) = a + b\ Ln(PP\ _{t-1}) + c\ Ln,(Urea\ price\ _{t-1}) + d\ Ln(P_{t-1})$

Where P_t = production at time t^{th} year, $P(_{t-1})$= production at $(_{t-1})^{th}$ year, urea price $_{t-1}$ = unit price of urea at the previous year, and PP_{t-1} is farm produce price at $(_{t-1})^{th}$ year.

Coefficients	Estimates	t- statistics
a	1.432	1.201
b	0.352	1.403
c	-0.022	-0.064
d	-0.477	-1.753

R2= 0.705, D-W statistic=1.991

The production estimation model of bajra with respect to farm produce price of bajra, urea price and production of the previous year could explain 70.5 per cent variation in the estimation. The major contributors in the estimation of bajra production were production and farm produce price of the previous year. The value of the D-W statistic also shows the absence of serial correlation amongst the errors and the strength of the relationship.

Feed estimation

$Ln(Feed\ at\ _t) = a + b\ Ln(PP\ _{t-1}) + c\ Ln,(Meat\ _{t-1}) + d\ Ln(Eggs_{t-1})$

Where P_t = feed use at time t^{th} year, and $PP_{(t-1)}$= farm produce price at $_{(t-1)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	8.851	0.503
b	-0.126	-0.060
c	0.009	0.829
d	-0.394	-0.132

R2= 0.184, D-W statistic=3.383

The feed estimation model of bajra with respect to farm produce price, and meat and egg production of the previous year could explain only 18.4 per cent variation in the estimated values. However, the D-W statistic value shows the strength of the model.

Food estimation

$Ln\ (P_t) = a + b\ Ln(PP\ _{t-1}) + c\ Ln(Rice\_price_{t-1}) + d\ Ln\ (Per\ Capita\ Income\ at\ _t) +$
$e\ Ln\ (Population\ at\ t)$

Where P_t = food use at time t^{th} year, and $PP_{(t-1)}$ = farm produce price at $_{(t-1)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	14.028	0.136
b	0.320	0.239
c	0.261	0.123
d	-0.212	-0.243
e	-0.936	-0.050

R2= 0.127, D-W statistic=3.390

The food estimation of bajra with respect to food production, rice price of the previous year along with per capita income and human population of the current year could explain only 12.7 per cent variation in the estimation. However, the D-W statistic value here also shows the absence of serial correlations amongst the errors.

Seed estimation

$Ln(P_t) = a + b\ Ln(PP\ at\ _t) + c\ Ln(meat\ at\ _t) + d\ Ln\ (eggs\ at\ _t)$

Where P_t = seed use at time t^{th} year, and PP = farm produce price of bajra at $_{(t)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	10.857	0.717
b	-0.366	-0.201
c	0.091	0.940
d	-0.380	-0.148

R2= 0.440, D-W statistic=2.982

The seed estimation model of bajra with respect to farm produce price, meat production and egg production could explain 44 per cent variation in the estimation. The D-W statistic value shows the absence of serial correlation amongst the errors and the strength of the model. The major contributor in the bajra seed estimation was meat production.

Waste estimation

$Ln(P_t) = a + b\,Ln(PP_{t-1}) + c\,Ln(Rice\_price_{t-1}) + d\,Ln(\text{Per Capita Income at }_t) + e\,Ln(\text{Population at }_t)$

Where P_t = waste use at time t^{th} year, and $PP_{(t-1)}$ = farm produce price at $_{(t-1)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	-12.7876	-0.101
b	-0.090	-0.933
c	0.018	0.007
d	-0.487	-1.211
e	3.529	1.380

R2= 0.060, D-W statistic=3.669

The waste estimation for bajra with respect to waste, rice price of the previous year along with per capita income and the human population of the current year could explain only 6.0 per cent variation in the estimation. However, the D-W statistic value shows the absence of serial correlation amongst the errors and the strength of the model for waste estimation of bajra.

Based on the above models, projections for the future status of bajra acreage and production for the coming 10 years (2002-2012) have been made (Table 2.2). The demand has been formulated on the basis of FAO statistics, where bajra produce shall be consumed for coarse cereals. Columns 2 and 3 of the table give projections for bajra area and production (supply) and Columns 4 to 7 refer to demand of bajra during the projection period. The projections of acreage and production do not show a regular increasing trend in estimation mainly due to the adoption of this crop in rainfed semi arid areas where rainfall plays a major role and the economy is subsistence.

Table 2.2 Bajra area and production projections in India

Year	Area (mha)	Production (mt)	Food (mt)	Feed (mt)	Seed (mt)	Waste (mt)
2002	8.93	13.65812	12.68751	0.13123	0.25937	0.58001
2003	9.42	9.59976	8.62759	0.13025	0.25583	0.58609
2004	8.96	11.46085	10.48716	0.12934	0.25259	0.59177
2005	9.26	10.62067	9.64548	0.12850	0.24958	0.59711
2006	8.97	11.10023	10.12358	0.12771	0.24680	0.60214
2007	9.14	10.94925	9.97117	0.12697	0.24420	0.60691
2008	8.95	11.09787	10.11839	0.12627	0.24177	0.61145
2009	9.06	11.09946	10.11860	0.12562	0.23948	0.61576
2010	8.93	11.16814	10.18593	0.12500	0.23733	0.61989
2011	8.99	11.20158	10.21804	0.12441	0.23529	0.62384
2012	8.90	11.24907	10.26423	0.12385	0.23336	0.62763

Source: Author's calculation.

2.3.3 Sorghum (Jowar)

Area estimation

$Ln(A_t) = a + b\,Ln(PP\text{ at }_{t-1}) + c\,Ln,(A_{t-1})$

Where A_t = area under production at time t^{th} year, $A_{(t-1)}$ = area under production at $_{(t-1)}{}^{th}$ year, and PP_{t-1} = farm produce price of sorghum at time $_{t-1}$.

Coefficients	Estimates	t- statistics
a	5.135	3.244
b	-0.394	-2.858
c	-0.212	-0.615

R2= 0.840, D-W statistic=1.956

The acreage estimation model with respect to farm produce and acreage of the previous year explains 84.0 per cent variation in the estimated values. The D-W statistic also supports the strength of the model. The major contributor in area estimation of this crop was farm produce price of the previous year.

Production estimation

$Ln(P_t) = a + b\ Ln(PP_{t-1}) + c\ Ln,(Urea\ price_{t-1}) + d\ Ln(P_{t-1})$

Where P_t = production at time t^{th} year, $P_{(t-1)}$ = production at $_{(t-1)}{}^{th}$ year, and PP_{t-1} = farm produce price at $_{(t-1)}{}^{th}$ year.

Coefficients	Estimates	t- statistics
a	-0.0687	-0.269
b	0.103	1.845
c	-0.161	-1.443
d	0.903	15.143

R2= 0.985, D-W statistic=1.148

The production estimation model of sorghum with respect to farm produce price of sorghum, urea price and production of the previous year explains 98.5 per cent variation in the estimation. The major contributors in the estimation of sorghum production were production and farm produce price of the previous year.

Feed estimation

$Ln(Feed\ at_{t}) = a + b\ Ln(PP_{t-1}) + c\ Ln,(meat_{t-1}) + d\ Ln(Eggs_{t-1})$

Where P_t = feed use at time t^{th} year, and $PP_{(t-1)}$ = farm produce price at $_{(t-1)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	5.708	0.333
b	-0.163	-0.136
c	-0.198	-0.544
d	-0.180	-0.078

R2= 0.401, D-W statistic= 2.691

The feed estimation model of sorghum with respect to farm produce price, and meat and egg production of the previous year could explain only 40.1 per cent variation in the estimated values. However, the D-W statistic value shows the strength of the model. The major contributor in the estimation was meat production at t-1 year.

Food estimation

$Ln(P_t) = a + b\ Ln(PP_{t-1}) + c\ Ln(Rice\_price_{t-1}) + d\ Ln\ (Per\ Capita\ Income\ at_{t}) + e\ Ln(Population\ at_{t})$

Where P_t = food use at time t^{th} year, and $PP_{(t-1)}$ = farm produce price at $_{(t-1)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	-45.854	-0.717
b	-2.112	-0.805
c	-1.776	-0.635
d	1.881	1.541
e	7.769	0.717

R2= 0.601, D-W statistic=2.291

The food estimation model of sorghum with respect to food production, rice price of the previous year, per capita income and human population of the current year could explain only 60.1 per cent variation in the estimation. However, the D-W statistic value here also shows the absence of serial correlation amongst the errors.

Seed estimation

$Ln(P_t) = a + b\ Ln(PP\ at\ _t) + c\ Ln(meat\ at\ _t) + d\ Ln\ (eggs\ at\ _t)$

Where P_t = seed use at time t^{th} year, and PP = farm produce price of sorghum at $_{(t)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	3.141	0.183
b	-0.163	-0.136
c	-0.198	-0.544
d	-0.180	-0.078

R2= 0.401, D-W statistic=2.691

The seed estimation model of sorghum with respect to farm produce price and meat and egg production explains only 40.1 per cent variation in the estimation. The D-W statistic value shows the absence of serial correlation amongst the errors and the strength of the model. The major contributor in the sorghum seed estimation was meat production.

Waste estimation

$Ln(P_t) = a + b\ Ln(PP\ _{t-1}) + c\ Ln(Rice\_price_{t-1}) + d\ Ln\ (Per\ Capita\ Income\ at\ _t) +$
$e\ Ln\ (Population\ at\ _t)$

Where P_t = waste at time t^{th} year, and $PP_{(t-1)}$ = farm produce price at $_{(t-1)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	-47.952	-0.750
b	-2.112	-0.805
c	-1.776	-0.635
d	1.881	1.541
e	7.769	0.717

R2= 0.601, D-W statistic=2.291

The waste estimation of sorghum with respect to farm produce price, rice price of the previous year along with per capita income and human population of the current year could explain 60.1 per cent variation in the estimation. The D-W statistic value shows the absence of serial correlation amongst the errors and the strength of the model.

The projections of sorghum acreage and production were made on the basis of evolved estimation models. The value for food, feed, seed and waste were calculated on the basis of discussion with the sorghum workers. It has been observed that although the acreage has been showing a decrease, production is considerably increasing (Table 2.3). Sorghum yield is expected to further increase in the coming decade due to more (soil and nutrient) responsive varieties of this crop.

Table 2.3 Area and production projections of sorghum in India

Year	Area (mha)	Production (mt)	Food (mt)	Feed (mt)	Seed (mt)	Waste (mt)
2002	9.80	7.591424	4.447323	3.502825	0.263536	0.545694
2003	9.73	7.759094	4.472631	3.433002	0.258669	0.548799
2004	9.64	7.913709	4.499414	3.369597	0.254218	0.552085
2005	9.56	8.055999	4.527120	3.311622	0.250124	0.555485
2006	9.49	8.186711	4.555367	3.258293	0.246339	0.558951
2007	9.43	8.306590	4.583880	3.208980	0.242822	0.562449
2008	9.36	8.416373	4.612466	3.163171	0.239542	0.565957
2009	9.31	8.516776	4.640984	3.120441	0.236471	0.569456
2010	9.25	8.608490	4.669335	3.080437	0.233587	0.572935
2011	9.20	8.692178	4.697445	3.042862	0.230869	0.576384
2012	9.15	8.768467	4.725264	3.007461	0.228302	0.579797

Source: Author's calculation.

2.3.4 Barley

Acreage function

$Ln(A_t) = a + b\ Ln(PP\ at\ _{t-1}) + c\ Ln(A\ _{t-1})$

Where A_t = area under production at time t^{th} year, $A_{(t-1)}$ = area under production at $_{(t-1)}{}^{th}$ year, and PP_{t-1} = farm produce price of barley at time $_{(t-1)}{}^{th}$ year.

Coefficients	Estimates	t- statistics
a	1.740	1.948
b	-0.155	-0.397
c	-0.377	-2.046

R2=0.408, D-W statistic=2.460

The acreage estimation model for barley could explain 40.8 per cent variation in the estimated values. The value of the D-W statistic shows the absence of serial correlation amongst the errors and the strength of the relationship. A significant contribution of barley farm produce price was observed in the estimation.

Yield estimation

$Ln(P_t) = a + b\ Ln(PP\ _{t-1}) + c\ Ln,(Urea\ price\ _{t-1}) + d\ Ln(P_{t-1})$

Where P_t = yield at time t^{th} year, and $P_{(t-1)}$ = production at $_{(t-1)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	0.677	1.194
b	0.255	1.424
c	-0.730	-2.386
d	-0.774	-2.586

R2= 0.573, D-W statistic=1.942

The yield estimation model for barley with respect to farm produce price, urea price and barley production of the previous year explains 57.3 per cent variation in the estimated values. The major contributor in the estimation was production followed by urea price and farm produce price of the previous year. The D-W statistic value also supports the strength of the model.

Feed estimation

$Ln(Feed\ at\ _t) = a + b\ Ln(PP\ _{t-1}) + c\ Ln,(meat\ _{t-1}) + d\ Ln(Eggs_{t-1})$

Where P_t = feed use at time t^{th} year, and $PP_{(t-1)}$ = farm produce price at $_{(t-1)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	23.823	2.817
b	1.706	1.472
c	0.005	0.054
d	-2.910	-1.931

R2= 0.564, D-W statistic=1.723

The feed estimation model of barley with respect to farm produce price and meat and egg production of the previous year explains 56.4 per cent variation in the estimated values. The D-W statistic also shows the absence of serial correlations amongst the errors. The major contributor in feed estimation was egg production of the previous year.

Food estimation

$Ln(P_t) = a + b\ Ln(PP_{t-1}) + c\ Ln(Rice\_price_{t-1}) + d\ Ln(Per\ Capita\ Income\ at_{\ t}) + e\ Ln(Population\ at_{\ t})$

Where P_t = food use at time t^{th} year, and $P_{(t-1)}$ = production at $_{(t-1)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	1.210	0.018
b	0.191	0.223
c	0.115	0.102
d	-0.438	-0.566
e	1.194	0.098

R2= 0.127, D-W statistic=3.390

The food estimation model with respect to food production, rice price of the previous year along with per capita income and human population of the current year could explain only 12.7 per cent variation in the estimation. However, the D-W statistic value here shows the absence of serial correlation amongst the errors.

Seed estimation

$Ln(P_t) = a + b\ Ln(PP\ at_{\ t}) + c\ Ln(meat\ at_{\ t}) + d\ Ln\ (eggs\ at_{\ t})$

Where P_t = seed use at time t^{th} year, and PP = farm produce price of barley at $_{(t)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	0.448	0.151
b	-0.396	-0.977
c	-0.088	-2.635
d	0.723	1.369

R2= 0.568, D-W statistic=2.693

The seed estimation model of barley with respect to farm produce price, and meat and egg production explains 56.8 per cent variation in the estimation. The D-W statistic value shows the absence of serial correlation amongst the errors and the strength of the model. The major contributor in the barley seed estimation was meat production.

Processing estimation

$Ln(P_t) = a + b\ Ln(PP\ at_{\ t}) + c\ Ln(meat\ at_{\ t}) + d\ Ln\ (eggs\ at_{\ t})$

Where P_t = processing at time t^{th} year, and PP = farm produce price of barley at $_{(t)}{}^{th}$ year

Coefficients	Estimates	t- statistics
a	-6.460	-0.792
b	0.325	0.291
c	0.025	0.270
d	0.879	0.605

R2= 0.759, D-W statistic=0.833

The seed estimation model of barley with respect to farm produce price and meat and egg production explains 75.9 per cent variation in the estimation. The smaller value (0.833) of the D-W statistic however, shows the presence of serial correlation amongst the errors and weakness in the model. The major contributor in the barley seed estimation was egg production.

The projections of barley for the coming decade show that barley will become a lower priority crop with dismal growth in the future unless the Government of India take steps to encourage this crop as a feed source for animal and poultry besides its use for the brewery (Table 2.4). From the view point of edaphic and rainfall deficiencies in land use, barley is economically a more viable crop, which needs emphasis.

Table 2.4 Barley area and production projections for India

Year	Area (mha)	Production (mt)	Food (mt)	Feed (mt)	Seed (mt)	Waste (mt)
2002	0.670	1.46	1.246348	0.100425	0.106302	0.098256
2003	0.679	1.50	1.251584	0.097605	0.106618	0.101362
2004	0.673	1.46	1.256452	0.095065	0.106911	0.104324
2005	0.668	1.48	1.261001	0.092759	0.107185	0.107160
2006	0.664	1.46	1.265271	0.090653	0.107441	0.109882
2007	0.660	1.47	1.269296	0.088718	0.107683	0.112503
2008	0.657	1.45	1.273102	0.086932	0.107911	0.115030
2009	0.653	1.46	1.276712	0.085275	0.108128	0.117474
2010	0.650	1.45	1.280147	0.083733	0.108333	0.119839
2011	0.647	1.45	1.283423	0.082292	0.108530	0.122134
2012	0.644	1.44	1.286554	0.080941	0.108717	0.124363

Source: Author's calculation.

2.3.5 Ragi (Eleusine coracana)

Acreage function

Ln (Area at time $_t$) = a + b Ln (Area at time $_{t-1}$)

The prediction model evolved, taking the previous year's area under ragi, could explain 93 per cent variation. The area under this crop is also declining significantly from the previous years'.

Coefficients	Estimates	t- statistics
a	0.15381	2.813426
b	0.704944	7.953899

R^2=0.926756 Adj. R2= 0.912107

Production function

Ln (Production at time $_t$) = a + b Ln (Production at time $_{t-1}$) + c Ln (Acreage at time $_{t-1}$)

The estimation model for ragi production explains 72 per cent variation in production. The acreage of the previous year was the signification predictor variable in the estimation.

Coefficients	Estimates	t- statistics
a	0.73079	0.486679
b	-0.15452	-0.41116
c	0.486679	2.536539

R^2= 0.724842 Adj. R2= 0.587262

Table 2.5 Ragi area and production projections in India

Year	Area (mha)	Production (mt)	Food (mt)	Feed (mt)	Seed (mt)	Waste (mt)
2002	1.66	2.350145	2.056245	0.117500	0.117500	0.058750
2003	1.29	2.345301	2.052065	0.117261	0.117261	0.058630
2004	1.66	2.341909	2.049129	0.117093	0.117093	0.058547
2005	1.40	2.339529	2.047065	0.116975	0.116975	0.058488
2006	1.67	2.337858	2.045613	0.116892	0.116892	0.058446
2007	1.48	2.336682	2.044590	0.116834	0.116834	0.058417
2008	1.69	2.335856	2.043870	0.116793	0.116793	0.058396
2009	1.54	2.335274	2.043362	0.116764	0.116764	0.058382
2010	1.68	2.334864	2.043005	0.116743	0.116743	0.058372
2011	1.57	2.334575	2.042752	0.116729	0.116729	0.058364
2012	1.67	2.334372	2.042575	0.116719	0.116719	0.058359

Source: Author's calculation.

The estimation for acreage and production in the coming decade shows that the area under this crop will continue to fluctuate in response to the previous year's acreage and monsoon trends. Production is almost static due to this crop being given reduced emphasis compared to rice and maize.

2.4 Comparison of the models

From an Indian perspective, changes in public policy are made according to the needs of the people in terms of five-year plans. The present estimates for acreage, production and their uses as feed, food, seed etc. have been made for different crops as per the formulated models in the study. The percentage variation (R^2-value) and the D-W statistic (to see serial correlation amongst errors) of the models for acreage and production of five crops are presented in Table 2.6.

Table 2.6 Model comparison with respect to acreage and production of different crops

Crop	Acreage		Production	
	R^2-value	D-W statistic	R^2-value	D-W statistic
Maize	0.816	2.26	0.973	2.291
Bajra	0.803	2.64	0.705	1.991
Jowar	0.840	1.96	0.985	1.148
Barley	-	-	0.573	1.942
Ragi	92.68	-	72.48	-

Source: Author's calculation.

Perusal of the table shows that the model formulated in the study for acreage explained maximum variation in estimation (R2= 0.84) in the case of sorghum followed by maize and bajra. The D-W statistic in acreage estimation was maximum (2.64) in the case of bajra with a minimum (1.94) in barley acreage estimation. For production, the highest value of R^2 was obtained in the case of sorghum followed by maize and bajra. The D-W statistic was maximum (2.291) in the case of the maize production estimation. Therefore, the models formulated are better from an Indian perspective.

Projection trends of acreage, production and utilization of maize have been presented in Figure 5.1. It was observed that the acreage and production of the crops would have a slight increment in the coming decade. The annual declining trend for jowar was more in area compared to production, which will increase in the coming years. This may be due to the introduction of improved varieties resulting in better production (Figure 5.2). For bajra, area and production will experience a slight decline with an alternate zigzag trend as observed in the last ten years (Figure 5.3). The annual declining trend in barley production was more at the beginning of the period and then it slowed down, showing that either more attention needs to be paid to this crop or that the full potential has not been exploited (Figure 5.4). In the case of ragi, the area under this crop shows erratic behaviour but production is almost static in the projected years (Figure 5.5).

3. Review of the Current Status

3.1 Livestock production and consumption

India has a large livestock population (Table 1.1) which is also the largest among the different countries of Asia and the Pacific. Taneja (1999) remarked, " they contributed 68.6 million tons of milk, 28.2 billion eggs, 44.3 million kg of wool and 4.14 million tons of meat (1992 basis). The value of the output from livestock was 897 billion Rs (1996-97) excluding draught power valued at 45-95 billion Rs in terms of fuel equivalent. Livestock production is primarily a small farm production system characterized by low input - low output, with the exception of poultry and to some extent dairying with cross bred cows and buffaloes which are not only sustainable but provide good economic returns. Around 80 per cent of the livestock are on marginal, small and medium holdings accounting for 53 per cent of the operated area. The majority of the livestock owners are below the poverty line. Average herd size per farm is 3.7 heads of cattle and buffalo. Small ruminants are mostly reared under nomadic (30 per cent) and sedentary (70 per cent) systems. Average herd size in nomadic systems is 40 sheep and 20 goats while in sedentary systems, the average herd size is 1.5 sheep per household. Pig production is mostly under scavenging systems practiced by the weaker section of the society. Poultry production is reasonably organized, 50 per cent of poultry meat and 56 per cent of the eggs are produced under intensive production systems". A comparison of livestock productivity with the world average (Table 3.1) shows that, except for buffalo milk and egg production, the productivity of all commodities from livestock is low. The situation is much worse for cow milk (less than 43 per cent). Per capita livestock product consumption showed a rising trend between 1983-2000 with maximum increases in chicken meat and eggs followed by milk (Table 3.2). The demand projections for milk, meat and eggs up to the year 2020 indicate maximum growth in egg production followed by milk (Table 3.3). Thus, the growth of per capita consumption of livestock products and the expected growth requirement for the future, demand aggressive planning and management to balance the needs. To achieve the current level of livestock production and its annual increment, the deficit in all the components of fodder, dry crop residues and feeds has to be met from either increasing productivity, increasing land area (not possible due to human pressure for food crops) or imports. The expected rise in milk yield may be sufficient to meet the demand for milk and milk products of the growing population but the projected deficits of animal meat (emphasis on monogastric animals) will require larger emphasis on coarse cereals as feed ingredients.

Table 3.1 Comparison of productivity of livestock (kg/animal milked or slaughtered/annum): 1999-2000

Commodity	India	World
Cow milk	945	2,175
Buffalo milk	1,425	1,391
Beef	103	204
Buffalo meat	138	140
Sheep meat	12	16
Goat meat	10	12
Pork	35	78
Chicken	0.9	1.4
Eggs	12	10

Table 3.2 Annual per capita consumption of livestock products (kg)

Product	1983	1999-2000	% increase per year
Milk	43.0	73.5	4.17
Mutton and goat meat	1.1	1.0	-0.53
Beef and buffalo meat	0.6	0.9	2.94
Pork	0.16	0.24	2.94
Chicken	0.3	0.7	7.84
Total meat	2.4	3.1	1.72
Eggs (nos.)	9.2	19.5	6.59
Fish	2.5	3.5	2.35

Table 3.3 Demand projections for milk, meat and eggs in the country (million tons)

Product	1998-99	2020	% increase per year
Milk	74.5	156.5	5..24
Meat	4.4	.8.9	4.87
Eggs	1.4	3.5	7.14

3.2 Aquaculture and inland fisheries

During 2000, world aquaculture production reached 42.77 million tons with an increase of 8.9 per cent over the previous year. It is currently valued at US$ 65 billion annually. Fish production is a dynamic market with a growth rate of 10 per cent depending upon the country and species. China is the largest producer. Aquaculture encompasses nearly 200 species in contrast to terrestrial farm animal species. Much less practical information exists concerning the dietary nutrient requirements (Chadha, 2002).

India is gifted with a 1,311 km long coastal line. During 2000-01, India exported 440,473 tons of seafood worth US$ 1.4 billion. The exports are expected to increase to US$ 2.5 billion by 2005-06 from an initial level of 15,732 tons worth Rs 39 million in 1961-62. In Indian seafood exports, cultured shrimp accounts for 76 per cent of total shrimp exports and 53 per cent of the total exports of marine products. Frozen shrimp accounted for 25.4 per cent by volume and 69.6 per cent by value of the total exports of marine products. The shrimp farming industry picked up in 1980, slowed down by 1990 but has again started picking up. The world's average per capita per year availability of fish is 2.1 kg per person.

The global aqua feed tonnage for the year 2000 was considered as 15 million metric tons. Of this, 90 per cent was from Asia, 5 per cent from Europe, less than 2 per cent from South America, 2 per cent from North America and less than 1 per cent from Africa, the Middle East and Oceanea. In fish feed, soy meal and full fat soya are incorporated as opposed to fish meal. The use of oil meals is likely to grow. In India, the use of fish feed and its quantity of use is difficult to estimate since it is mostly in the unorganized sector. There appears to be little competition from the livestock industry since most of the use of food grains is of broken rice or wheat flour. Although the use of oil cakes/meals is increasing, it is still at a slower pace (Paul Raj, 1995).

3.3 Historical development of the animal feed sector

3.3.1 Feed crops and feed ingredients

3.3.1.1 Coarse cereals

India is one of the important consumers and producers of coarse cereals in the world. However, in contrast to animal feed use in developed countries it is a staple food for the poor in India and is a source of income and employment. Most of the coarse cereals in developed countries are used for cattle feed and some of the cereals like barley are processed for beer.

About half of the total world production of cereals is coarse cereals (Table 3.4). In India it is only 15.6 per cent of which about 2 per cent is utilized for feed except in the case of maize where 53 per cent of the production is utilized for poultry and animal feed.

Table 3.4 Significance of coarse cereals (million tons)

		India	USA	World
Total cereals MT	Cereals total	188.43	332.44	1,872.1
	Feed	1.77	164.1	655.1
% feed of total cereals		0.94	49.37	34.99
Wheat + Rice MT	Wheat + Rice	159.02	68.8	988.67
	Feed	1.20	7.72	104.6
% feed of total cereals		0.75	11.22	10.58
Coarse cereals MT	Coarse cereals	29.41	263.64	883.46
	Feed	0.57	156.4	550.4
% feed of total cereals		1.94	59.32	62.3
% coarse cereals of total cereals		15.61	79.3	47.19
% four coarse cereals of total cereals*		15.61	78.56	43.82

*Four major coarse cereals are barley, maize, millet and sorghum.
Source: FAO Bulletin of Statistics Vol. 1 No.2, 2000.

Maize, sorghum and millet are the major components of the coarse cereals in India with 10.78, 8.7 and 8.47 million tons of production respectively (Table 3.5).

Table 3.5 Major coarse cereals production (million tons)

Country	India	USA	World
Barley	1.47	6.10	127.56
Maize	10.78	239.55	605.61
Millet	8.47	0.40	26.89
Sorghum	8.70	15.12	60.33
Coarse cereals –major coarse cereals	29.42	261.17	820.39
Total	29.41	263.64	883.46
% major coarse cereals to cereals	15.61	78.56	43.82
Coarse cereals per cent in the world	3.33	29.83	100

Source: FAO Bulletin of Statistics Vol. 1 No.2, 2000.

Trends in production

Annual growth of total cereals in India between 1961 to 1999 was 2.82 per cent (Table 3.6). This growth kept pace with the population growth of about 2 per cent and the increase in income. The growth was mainly contributed by wheat and rice while coarse cereals, except maize, had declining or lower growth rates. The growth rate for millet and sorghum was 0.46 per cent and 0.23 per cent respectively while barley had a negative growth rate of -1.96 per cent. The growth rate for maize was 2.28 per cent. The growth was contributed by yield in the case of total cereals. Cultivated area under rice and wheat increased while it declined for all coarse cereals with the exception of maize. Average yield of all the cereals in India is lower than the world average

Table 3.6 Growth rates of major crops in the world and India between 1961-1999

Commodity	Growth rates (%)						Yield (kg/ha)	
	Area		Production		Yield			
	World	India	World	India	World	India	World	India
Wheat	0.08	1.90	2.41	5.24	2.33	3.28	2,761	2,583
Rice	0.58	0.59	2.53	2.70	1.94	2.10	3,888	3,007
Barley	0.04	-4.13	1.28	-1.96	1.24	2.26	2,393	1,882
Maize	0.74	0.61	2.79	2.28	2.04	1.66	4,358	1,655
Millet	-0.61	-1.28	0.09	0.46	0.71	1.76	748	722
Sorghum	-0.32	-1.45	0.63	0.23	0.95	1.70	1,426	826
Coarse cereals	0.20	-1.18	2.13	0.68	-1.89	1.88	3,032	995
Total cereals	0.08	0.15	2.15	2.82	-2.02	2.66	3,098	2,308

Source: FAO Bulletin of Statistics Vol. 1 No.2, 2000.

Coarse cereal production variability was very high compared to other cereals. The data indicates that the coefficient of variation was 15 per cent or more in the case of coarse cereals while for rice and wheat it was less than 10 per cent (Table 3.7). This shows the stability parameter which ultimately affects the growth. At this stage it is technology that helps the commodities to compete and determines crop size. In the case of pearl millet, technology helped production and reduced the variability. In Gujarat state, pearl millet and groundnut compete with each other. Their coverage area moved in opposite directions and showed that coarse cereals can compete with cash crops like groundnut (Bapna, 2001). This was possible due to high yielding varieties of pearl millet, which brought the per hectare yield to the level of groundnut. It can be observed from the resultant lower variability in pearl millet yield compared to groundnut, a decline in the price of pearl millet and price increases of groundnut (Bapna, 2001).

Table 3.7 Variability in the production of different crops in India

Crop	Barley	Maize	Millet	Sorghum	Rice	Wheat
% variability in production	16.19	11.51	15.99	13.75	9.03	7.86

Source: Bapna, 2001.

3.3.1.2 Maize

Maize is a top ranking cereal in terms of global productivity. It is second to wheat in total production and has great significance as a human food, animal feed and industrial products. It is also called the queen of cereals and occupies a 20 per cent area of the cereals. It has a 25 per cent share in the developed market economies. The annual yield growth rate is 2.5 per cent (1973-82) to 3.2 per cent (1999-2000). The average yield is at a maximum (9.5 t/ha) in Italy followed by France (8.8 t/ha) and USA (8.25 t/ha). The average yield in India was very low (1.8 t/ha) but this year it reached 2.06 t/ha. Maximum production of maize comes from USA (48 per cent) followed by China (23 per cent). India contributes only 2 per cent to world maize production. Global maize demand is increasing fast (50 per cent increase, Table 3.8). It is expected that the global demand for maize will surpass demand for rice and wheat. The production trend in maize is linear.

Table 3.8 Global maize demand (million tons)

	1996	2020
Industrialized countries	216	412
Developing countries	261	331
Total	477	743

Maize occupies a 26 per cent area in India and contributes 41 per cent to production from the three coarse cereals maize, sorghum and pearl millet. The major states from a yield point of view are Andhra Pradesh, Karnataka and Punjab but maximum production comes from Karnataka, Bihar and Uttar Pradesh. In India, maize is cultivated in both seasons with a maximum in the rainy season (*Kharif*) but the yield in winter (*rabi*) is higher (Singh, 2001). It is expected that the hybrid technology and winter maize have a high potential for production improvements. Maize occupies third position in cereal production in India and among the coarse cereals it has a 35 per cent share (Table 3.9). It is primarily consumed for poultry feed (up to 50 per cent in broiler feed and up to 70 per cent in layer feed), human food (26 per cent), livestock feed (12 per cent), starch (10 per cent) and seed use (2 per cent). Quality protein maize (QPM) has a very high potential for improving the nutritional balance in humans and animals.

Production of maize has remained almost stagnant at around 10.8 million tons from 1996-97 onwards. During 1999-2000 the output was reported to be at 10.78 million tons. During 2001, production was 13.5 million tons with a yield of 2.06 t/ha on a 6.5 million ha area. Kharif maize has slightly declined from about 9.2 million tons in 1998-99 to 9.11 million tons in 1999-

2000. The growth of production of maize, which increased by 2.33 per cent per annum during the eighties, accelerated to 2.92 per cent per annum during the nineties. The marginal improvement in the growth rate of output was due to the expansion in area from (-) 0.1 per cent per annum during the eighties to 0.74 per cent per annum during the nineties. The growth of productivity, on the other hand, has slightly decelerated from 2.42 per cent to 2.16 per cent between these two periods.

Maize has been under the Technology Mission set up by the Government of India for promoting production technology and superior varieties of maize in the country since 1995. From 1996-97, production of this crop has remained almost steady. Efforts to evolve new varieties and extend the crop to the rabi season have been to a large extent helpful in maintaining the level of production. The Technology Mission's Ninth Plan target was to increase the production and productivity of maize to 15.2 million tons and 2.4 tons per hectare by 2000-2001. For this purpose, a comprehensive programme has been chalked out, which includes assistance to the Indian Council of Agricultural Research (ICAR) for the production of nucleus, breeder and foundation seeds of maize, front line demonstrations on improved production technology and integrated pest management and incentives for farmers for the use of certified seeds of hybrid and improved varieties. The ICAR has already released region specific high yielding seeds with mean yields ranging from 2.5 to 5.0 tons per hectare. Front line demonstrations and field trials conducted by the ICAR are reported to have realized yields of maize upto 6.31 tons per hectare. However, the average yield of maize, at present, is only 2.06 tons per hectare, which is slightly lower than the proposed target of 2.4 tons per hectare for 2000-2001. The ICAR has indicated that the supply of quality seeds at the proper time, improvement of irrigation facilities, application of fertilizers at recommended doses, and control of insects, pests and diseases are some of the crucial areas requiring attention if production and productivity of this crop is to be increased as targeted. Recently, quality protein maize has been promoted to bridge the nutrition deficiency gap in food in the country.

Quality protein maize

- High content of lysine and tryptophan, and essential amino acids which are deficient in normal maize kernels.
- Better balanced amino acid composition in the grain.
- Taste and appearance of kernal like normal maize.
- Good agronomic performance.
- Tolerance to major insect pests and diseases.

Table 3.9 Share (%) of different crops in production in India

Crop	% share in production (1999-2000)	% share in coarse grain production
Rice	44	
Wheat	36	
Maize	5	35
Pulses	6	
Sorghum	4	29
Pearl millet	3	19
Other coarse cereals	2	17

Source: Singh, 2001.

Demand is expected to increase due to the consumption of food and feed, continued population growth and rises in income but the production growth rate is low. This year, 12.6 million tons of maize have been produced on a 6.55 million ha area (2002).

3.3.1.3 Sorghum

Sorghum is the most important cereal crop for poor people and grown for food, feed and industrial products. It was grown over an area of 18 million ha with production in the late 1960s at 9 million tons, in contrast to the present area of 10.4 million ha with almost a similar level of production (8.3 million tons). It is important to note the current sorghum scenario in the country where in *rabi*, sorghum area (5.64 million ha) has become larger in proportion (54 per cent) than the (46 per cent) area left under *kharif* (4.76 million ha). Sorghum is also grown for forage in northern India over an area of 2.6-3.0 million ha.

Kharif (rainy season) sorghum is an important traditional crop for the mixed farming system under the dryland ecosystem of Indian agriculture. With the hybrid technology for sorghum, rainfed areas have become potentially productive. The jump in productivity from 0.5 t/ha (1970) to 10.2 t/ha in 1996 has been a great achievement but the area under *kharif* sorghum has declined from 11.52 million ha (1970) to 4.76 million ha (1996). The area diversion has taken place for oil seeds, pulses, cotton etc. This has been mainly due to economic reasons, indicating that the cropping patterns have been market driven (Rana *et al*., 2001). A comparison of the *kharif* and *rabi* sorghum area and productivity in *rabi* sorghum growing states indicates low productivity of the *rabi* sorghum although the area is increasing. This is mainly because the *rabi* sorghum grains are priced double compared to the *kharif* grains as it is preferred for human food. Its fodder is equally valuable (Table 3.10).

Table 3.10 Area (million ha) and grain yield (kg/ha in parenthesis) of *kharif* and *rabi* sorghum in major *rabi* sorghum growing states of India

Season	Maharashtra	Karnataka	Andhra Pradesh	Total
Kharif	1.96 (1317)	0.41 (1391)	0.33 (725)	2.7 (1256)
Rabi	3.18 (550)	1.52 (667)	0.44 (655)	5.14 (594)

The compound growth rate of area, production and yield between the two periods indicates a negative growth rate in area of the *kharif* crop but the overall yield has always shown a positive rate of 1.78 per cent per annum. This slightly declined between 1980-2000 (Table 3.11).

Table 3.11 Compound growth rate (%) of sorghum area, production and yield

Season	Period	Area	Production	Yield
Kharif	1967-68 to 99-2000	-2.352	-0.146	2.259
	1980-81 to 99-2000	-4.262	-2.294	2.058
Rabi	1967-68 to 99-2000	-0.636	0.685	1.329
	1980-81 to 99-2000	-0.932	0.521	1.462
Total	1967-68 to 99-2000	-1.612	0.136	1.781
	1980-81 to 99-2000	-2.800	-1.343	1.501

Sorghum based cropping systems

Sorghum with red gram as an inter-crop is found to be remunerative in 2:1 or 3:3 row proportion. Alternatively, sorghum and fodder cowpea as an inter-crop in the ratio of 2:2 is also profitable. In the inter-cropping systems, the yield of grain and fodder from the sorghum crop is similar to its sole cropping. Hence, the gain from the inter-crop is additional. In the deep black soils, having adequate rainfall, sunflower or Bengal gram can be grown after *Kharif* sorghum. The sequence crop should be sown without disturbing the land and sorghum stubble. For this, it is better to harvest the sorghum crop one week in advance, at the physiological maturity stage, than, as is commonly followed, at full maturity to retain the required moisture in the upper portion of the soil for the proper germination of the succeeding crop. In the *maghi* (late k*harif* or early *rab*i) and *rabi* sorghum cultivated areas, sowing of short duration crops like green gram or black gram in *kharif* followed by sorghum is profitable. The inter-cropping of soybean-sorghum in 4:2 or 6:3 row ratio and groundnut-sorghum in 3:6 row ratio is also recommended for those areas where sorghum has been replaced by soybean and groundnut.

Use as animal feed

Sorghum grain can be nutritionally a better feed due to its high protein and fibre content. Bagasse of sweet sorghum bio-enriched with microorganisms can be a good cattle feed as the demand for feed is rising at a rate of 4 per cent per annum. Indian white grain sorghum has very low or zero tannin content in contrast to brown or red sorghum from other countries. In poultry feed, maize can be replaced by sorghum to the extent of 50 per cent without altering the egg laying potential (81.1 per cent) and broiler weight. If inclusion of sorghum in feed is to be maintained at 20 per cent, 3 million tons of sorghum would be required for this purpose alone (Rana *et al.*, 2001). Cattle feed manufacturers buy sorghum during July-August when its price is relatively lower than maize but in October the maize price falls and they switch over to maize. Currently, it is estimated that 80 per cent of the kharif grain is used as feed while 3 per cent for alcohol manufacture.

Development strategies for improving productivity and profitability

- Introduction of kharif dual purpose varieties which can act as single cut fodder cultivars.
- Introduction of intercropping with sorghum where sorghum has been replaced by low canopy, high value crops like soybean and groundnut.
- Summer sorghum cultivation.
- Introduction of sorghum in rice fallows.
- Enforce seed purity issues.
- Ensuring assured seed production of public sector hybrids and varieties.
- Technology transfer for improved productivity through front line demonstrations.
- Remove the government policy based limitations.
- Emphasize high potential irrigated rabi crop.
- Promoting alternate uses other than food of kharif sorghum grain.

Other uses

Sorghum is also used for the manufacture of bakery products, alcohol, starch and starch by-products, high fructose syrup, glucose, malt, beer and adjunct (in the brewing industry). Ethanol as bio-fuel from sweet stalks, natural syrup and jaggary are yet more products.

3.3.1.4 Barley (Hordeum vulgare)

Barley is an important coarse cereal in India. Barley is a crop useful for food grains, fodder, malt breweries, pearl barley, livestock feed and poultry feed. Suitable agro processing techniques in future can bring barley to the level of a foreign exchange earning crop. It is also used as a constituent of soup and breakfast food. The barley grain contains 12 per cent protein, 1.4 per cent fat and as such is not less than wheat in its nutritional quality (Singh, 1999). The area under barley cultivation in the country declined from 3.4 million ha in 1967-68 to 1.8 million ha in 1980. After 1990, it has further come down to 0.85 m ha. This represents slightly more than 1 per cent of the total area under barley in the world.

Present barley production in the country has also shown a decline from 3.5 million tons (in 1967-68) to 1.63 million tons in 1990 and is presently 1.5 million tons. The level of productivity has increased from 1 t/ha in 1960 to 2.0 t/ha presently. In a global context it is still low. It is considered that barley is a crop most suited to dry climates, poor quality irrigation, drought conditions, poor fertility and saline - sodic conditions. Barley along with other coarse cereals like pearl millet, ragi, etc have lost much ground to wheat and other commercial crops during the course of the green revolution. It is also considered that the cultivation of barley in

India is a marginal affair. Its cultivation is normally taken up by poor farmers whose land holdings are small and of low productivity, mostly in the states of Rajasthan, Haryana, Madhya Pradesh. and Uttar Pradesh.

Barley cultivation as fodder

Barley has also been recommended as green fodder and considered superior in quality and quantity to oats, however, in Rajasthan state it has not become popular (Anon 1998). It is recommended for harvest as green fodder at 50 days after sowing, followed by grain production. The production of green fodder at 20-25 t/ha, in addition to 3 t/ha of grain at maturity is reported. Considering the average grain production of 2.18 t/ha in the country, it is profitable to harvest green fodder to meet the fodder demand in scarcity areas. It is also recommended for growing to mix with lucerne for fodder compared to lucerne + oats.

3.3.2 Agro based industries and by-products

In India during 2000-01, the total availability of oil meal was 15.82 million tons of which 2.35 million tons (2.18 soy, 0.003 groundnut cake and 0.167 million mt others) were exported. The balance of 13.27 million tons was left for the domestic market. This included 4.05 million tons of cotton meal, 2.55 million tons of rice bran and 1.42 million tons of other minor meals, 1.32 million tons of soy meal, 1.88 million tons of groundnut meal and 2.05 million tons of rapeseed meal. The availability of soy meal after export for the local feed industry is insignificant (only 1.32 million tons).

3.3.3 Livestock feed industry

Livestock feeds are manufactured by industries under the banner of "Compound Livestock Feed Manufacturer's Association of India" (CLFMA) and also some other small cooperatives. This association was formed in 1967 with the objective of helping the promotion of the concept of balanced feeding of animals in accordance with their nutritional requirements for deriving maximum output through productivity improvement. They have an installed capacity of over 5 million tons/year and produce over 3 million tons/yr. Other small industries in the unorganized sector produce 2 million tons/yr, thus, making a total of 5 million tons/yr against the demand of 42 m t/yr. Many poultry industries have established their own feed milling facility and the required research and development to take care of the quality. Several State Agro-industrial Corporations have also started manufacturing the feeds. Demand for compound animal feeds is growing at a rate of 12 per cent. CLFMA is broad based with membership of manufacturers and suppliers of feed additives, raw materials, packaging materials, feed plants and machinery, laboratory equipment, meat processors and exporters, dairy processors and others connected with the Indian livestock industry. CLFMA activities are as follows:

- CLFMA has set up modern and efficient feed mills, with facilities for analytical testing of feed raw materials and finished feeds for providing quality assurance.
- CLFMA has evolved standard specifications for compound feeds for cattle, poultry, pigs and also for the purchase of feed raw materials, which should help in providing quality assurance to farmers.
- CLFMA organizes/conducts National Symposia, seminars and orientation courses at veterinary colleges, farmer's workshops and other educational programmes.
- It encourages applied research – CLFMA awards for the best research work in India.
- CLFMA collects, classifies and circulates technical, managerial and statistical information, besides information on government policies – on-line latest news and information.
- Makes representations to central and state governments and submits suggestions, thus providing a strong platform to voice the views of the industry.

- CLFMA sponsors research/surveys/and studies, which are necessary and helpful for the growth of livestock industry.

Taneja (1999) remarked that "The compound feed industry, while helping with the optimal utilization of coarse grains, agro-industrial by-products such as de-oiled meals and other non conventional raw materials, also provides nutritionally balanced and scientifically compounded animal feed with high conversion efficiency, and therefore enables a greater quantity of animal products with less feed. This is of great significance in view of the shortage of feed in India."

3.4 Agricultural policies

3.4.1 Production policies

For the growing human population, present food grain production of 200 million tons/yr has to be doubled by the year 2020. This is expected to come from improving productivity in the rainfed areas and also the eastern zone of the country. A mean productivity level of 4 t/ha/yr from irrigated and 2 t/ha/yr from rainfed areas is targeted to achieve it. Although in rainfed areas emphasis has to be on pulses and oil seeds, coarse cereals are also emphasized in specific zones for meeting the requirement of the livestock sector. Total oil seed production in India has a declining trend, from 31.5 million tons in 1998-99 to 25.26 million tons in 2000-01. The emphasis still continues to remain on wheat and paddy as staple crops since their production and prices have very low variability.

3.4.2 Agro-processing policies

Processing of raw materials viz., food grains, livestock products, horticultural products etc. and the development of post harvest technology is essential to maintain its shelf life, efficient marketing and exports. During the last 7-8 years, the milk, broiler, egg, meat and fish sectors have seen steady growth rates. Milk processing capacities have kept prices under control and driven demand. The same has also happened in the poultry sector. The key driving factor in the domestic sector is the rising income levels that are raising disposable income and living standards impacting demand positively. In every sector of agriculture, processing and value addition, packaging and storage are being emphasized to keep markets regulated and provide standard products to the consumers.

3.4.3 Pricing policies

Real prices of coarse cereals were stagnant after the mid seventies but that of rice and wheat declined. Coarse cereal prices rose at a rate of 1.48 per cent per annum while that of rice and wheat declined by 1.6 and 1.97 respectively. These differences in growth rates should be seen in light of low or negative growth of coarse cereal production and high growth in the production of rice and wheat. With increases of 3-5 per cent per annum in the latter cereals and little growth in coarse cereals, it may be said that price is maintained at a level that is keeping pace with demand, or demand is adjusting to price. While for rice and wheat, very high growth has led to a decline in the real price. As a result of these factors and the gap between coarse cereals and wheat and rice, prices have fallen gradually. Coarse cereal prices have generally remained lower than wheat and rice prices.

The government's programmes of procurement and support prices for coarse cereals encouraged very little procurement of coarse cereals. The price variability in coarse cereals was compared to the heavily supported wheat and rice. It was observed that prices of coarse cereals fluctuated more than wheat, rice, oil seeds, pulses and cotton. The variability in millet price was 35.56 per cent compared to 14.66 for oil seeds, 25.09 for cotton and 25.06 per cent for wheat (Table 3.12).

International price comparisons indicate that the price of coarse cereals was much lower in the world market with the exception of millets. This means that as WTO processes are implemented, Indian coarse cereals could face competition from other countries that may have comparative advantage. However, if subsidies in western countries are removed or reduced, India may have comparative advantage. If India does not have comparative advantage, even after globalization, technology and farming research will have to bring out new crops/varieties which can fit in to the agroclimatic conditions of coarse cereal growing areas. Otherwise farmers will be left with less profitable crops and only subsistence farmers will survive the adverse effects of globalization because of the use of family labour on their farms. Farmers with a marketable surplus will face a decline in income.

Table 3.12 Growth rates and coefficient of variation of real prices of important commodities in India (1961-1999)

Commodity	Growth rates	CV (%)
Wheat	-1.97	25.06
Rice	-1.67	21.72
Superior cereals	-1.83	22.08
Barley	-1.25	29.87
Maize	-2.07	29.94
Millet	-1.72	35.56
Sorghum	-0.80	30.11
Coarse cereals	-1.48	26.85
Oil seeds	0.45	14.66
Pulses	1.34	18.01
Cotton	-0.26	25.09

3.5 Marketing and trade policies

3.5.1 Monetary and exchange rate policies

All the relevant factors are taken into account while fixing the minimum support price, viz., level of production, behaviour of market prices, inter-crop price parity, stocks, distribution and supply-demand balances, level of input prices, cost of production and terms of trade between agricultural and non-agricultural sectors, etc. In the present liberalized economy, world prices are also considered in a long-term context, taking into account the weighted average of international prices over a few years and also their coefficient of variation. Trade, transport margins and tariffs are also taken into account. Except for oil seeds, there is wide variation in all other grains. Thus, the international prices for most of the coarse grains remain lower than the market price. The moderation of minimum support prices of coarse grains are applied due to these factors even if their cost of production is high. Even though support prices are announced, there is very little purchase by the government. The market adjusts to demand. This year (2002), due to drought, bajra prices in the market are up 40 per cent.

3.5.2 State trading enterprise

Trade is regulated by the State Trading Corporation (STC) and NAPUED at the central government level. These organizations do not really deal with coarse cereals and thus, they are left to the private unorganized markets.

3.5.3 Policies most affected by international agreements

Oil meal exports are declining while their domestic consumption is increasing. In 1995-96 the ratio of domestic consumption and export was 76 to 24, becoming 85 to 15 during 2000-01. Therefore, the solvent extraction industry, farmers, state and central governments, missions and departments like the Technology Mission on Oil Seeds and Pulses are striving hard for bringing about rapid increases in production of oil seeds by improving their productivity. The major emphasis, however, remains on cash crops and rice and wheat. The production policies depend upon the market forces.

3.6 Policy reforms initiatives

Policies are regularly monitored, updated and evolved to facilitate higher productivity and growth of the sector. An adequate quantity of oil seeds and oil cakes for crushing are regularly needed for solvent extraction units. The gap between demand and supply of indigenous production is proposed to be allowed to be freely imported without import duty. This will ensure the provision of edible oils for humans and oil meals for livestock feeding with a price advantage of animal products to the ultimate consumers. Thus, the government’s policy has been catering the needs of all concerned: seed growers, crushers and processors as well as consumers of oils and oil meals. It is essential not to export the oil seed but to export only the oil so that the cake and meals are available to the livestock industry.

4. Demand for Feed Stuff and Feed Crops

4.1 Consumption behaviour

Based on the consumption behaviour and average rate of feeding of concentrates for different categories and species of livestock the demand has been calculated (Table 4.1). It shows a growing trend over the next ten years. It is noteworthy that maximum demand is for cattle followed by buffalo and poultry. Chadha (2002) estimated the requirement of total feeds (by a conservative estimate) to be 42 million tons out of which 28.75 million tons was for cattle and 13.25 million tons for poultry feeds. He projected for 2010 an increase to 30 million tons for cattle and 38 million tons for poultry making a total of 68 million tons. No estimate for buffalo or small ruminants was given. The estimates for poultry are closer to the estimates of Chadha (2002). The basis for these estimates are as per the nutritional needs (Appendix Table 1) projected by the Working Group on Feeds, Planning Commission (2001). The calculated demands are as per the population growth trends of the livestock.

Table 4.1 Projected estimates of annual requirements of concentrate feeds (million tons) in the coming decade (based on standard feeding practices and nutritional requirements of different species of livestock)

Livestock species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Buffalo	41.567	42.568	43.593	44.643	45.718	46.819	47.947	49.102	50.284	51.495	52.736
Cattle	56.126	57.260	58.417	59.597	60.801	62.029	63.282	64.560	65.865	67.195	68.553
Sheep	0.130	0.133	0.136	0.139	0.142	0.145	0.148	0.151	0.155	0.158	0.162
Goat	0.110	0.111	0.112	0.113	0.114	0.115	0.116	0.117	0.118	0.119	0.120
Pigs	1.414	1.471	1.531	1.594	1.659	1.726	1.796	1.869	1.945	2.025	2.107
Equine	0.970	0.981	0.993	1.004	1.015	1.027	1.039	1.050	1.062	1.075	1.087
Poultry	14.030	14.836	15.688	16.588	17.541	18.548	19.613	20.739	21.930	23.189	24.521
Total	114.347	117.360	120.470	123.678	126.990	130.409	133.941	137.588	141.359	145.256	149.286

This demand is an ideal requirement to meet the nutritional and production levels (Appendix Table 1). Most of the dry herds, sheep, goats and local breeds of animals do not receive the required quantity of animal feed of desired quality. Considering the estimates of Taneja (1999) it has been found that the deficit is only 47 per cent against this estimate giving a 64.27 per cent deficit. The consumption of feeds has to increase in view of the emphasis on crossbred herds for milk, poultry and pig production. Considering the rural poultry sector and the large number of local cattle, the feed requirement could be downsized since it is met by local domestic availability.

4.2 Consumption structure

Major consumption is shown for cattle where the population is large but only 26 per cent are of an improved type. For the remaining 74 per cent, despite having only a 0.5 kg/ha/yr requirement, even this is scarcely available. Since large numbers of local cattle are reared in the rural household sector they are given the food waste and some bran/oil cakes. Similarly, in the case of goat and sheep, the nomadic and rural flocks receive hardly any concentrates. For poultry, 35 per cent are reared in the rural sector where again the required level is not fed due to limitations. Livestock are the backbone of Indian agriculture and depend upon domestic supplies of nutrients but only a small proportion receive feed as per their standards.

4.3 Consumer price behaviour

The prices of these commodities have been increasing but the major component of the oil cakes and oil meals in the concentrate determines price behaviour. In the case of most of the small dairy units, household production often replaces expensive concentrates. Since most coarse cereals are priced low they are used in even higher proportions in the home made concentrate mixtures.

The consumer price behaviour of the commodities shows great diversity in the case of coarse grains compared to other cereals. Changes in the support price in the past 10 years have shown almost similar trends for coarse cereals and paddy (Table 4.2). In the case of wheat, it has shown a higher change indicating the pressure on the growers and the input costs. The percentage change in yield shows a better situation for coarse cereals except for sorghum. However, the changes in return per ha show a maximum for ragi followed by wheat. The return from other coarse cereals is in no way less than paddy but still emphasis on crops is determined by the easy availability of inputs like water for irrigation, fertilizers, good soils, etc. and the assured market price.

Table 4.2 Changes in support prices (MSP) of different commodities and in gross returns

Commodity	Minimum support Price (Rs/kg)		% Change	Yield (t/ha)		% Change	% Change in return/ha
	1990-91	2000-01		1990-91	2000-01		
Paddy	2.05	5.10	148.8	2.588	2.904	12.2	179.21
Wheat	2.15	5.80	169.8	2.216	2.615	18.01	218.34
Sorghum	1.80	4.45	147.2	0.793	0.795	0.21	147.74
Bajra	1.80	4.45	147.2	0.638	0.736	15.36	185.20
Ragi	1.80	4.45	147.2	1.100	1.428	29.86	221.00
Maize	1.80	4.45	147.2	1.515	1.743	15.05	184.43
Barley	1.80	4.30	138.9	1.596	1.905	19.34	185.08

The situation for coarse cereals is very much different than wheat and paddy. Demand plays a major role in deciding their market price. This year, due to drought, market prices of these coarse cereals in Rajasthan State are being quoted 40 per cent higher compared to the previous year. Since their area is declining and production is stable the aberrant weather plays a deciding role. For maize, this year, good production in South India has forced its major diversion to feed.

5. Supply of Feed and Feed Crops

5.1 Production behaviour

Where the estimates of production have been previously calculated through a model we find that the annual expected growth for maize has a rising trend for both area and production (Figure 5.1). It has been found that the production increase at the base year 2002 is expected to double, while area will also increase. Production behaviour of sorghum shows a reverse trend to that of maize (Figure 5.2). For bajra, area and production both show a declining trend (Figure 5.3). The production decline is in a negative direction. In the case of barley, area and production both show a decline (Figure 5.4).

5.2 Production structure

The supply of feeds has also been calculated based on many assumptions / factors that operate. As per the Department of Agriculture's recommendations, 5 per cent of the grains are used for feed, 5 per cent for seed and 2.5 per cent are wasted. Based on this assumption the calculation has been made. As per the Committee on Feeds, Planning Commission, the ratio is 10 per cent for barley, jowar, maize, ragi and small millets, 50 per cent for bajra, 2 per cent for rice and 3 per cent for wheat. In a recent communication from the Maize Directorate, New Delhi, 52 per cent of maize is used for livestock feed since it is the major component of poultry feed. Similarly in the case of sorghum, feed use has reached 39.1 per cent of annual production. All these form the basis for calculation of the supply scenario. Greater grain requirement is for monogastric animals for which maize and sorghum will continue to dominate among the coarse cereals while ragi is preferred for poultry because it helps poultry to tolerate higher temperatures.

5.3 Producer price behaviour

The existing price trend of coarse cereals in the domestic and international market indicates that wheat and rice are the preferred commodities as staple foods domestically as well as globally, whereas, coarse cereals will provide competition for cattle feed and industrial uses. The proposal relating to the use of ethanol to the extent of 5 per cent with petrol has been implemented by the government. It may induce firmness in the price of coarse cereals provided the manufacture of ethanol from coarse cereals is found to be cost effective in comparison to other sources. Yet the production of coarse cereals is required to be regulated to such an extent that these crops are competitive in trade as well as to the farmers. The emphasis on organic foods may further help boost the production of coarse cereals, which are also called nutri-cereals. Under such a situation prices are expected to remain stable and remunerative for the farmer, which may further make coarse grain crop farming more remunerative.

Figure 5.1 Production and use of maize in the coming decade

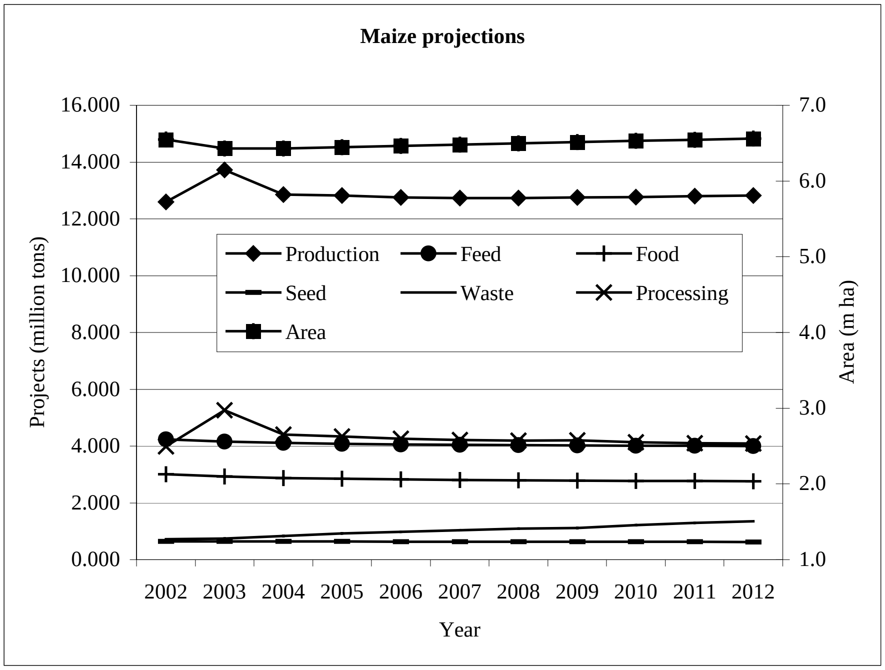


Figure 5.2 Production and use of sorghum in the coming decade

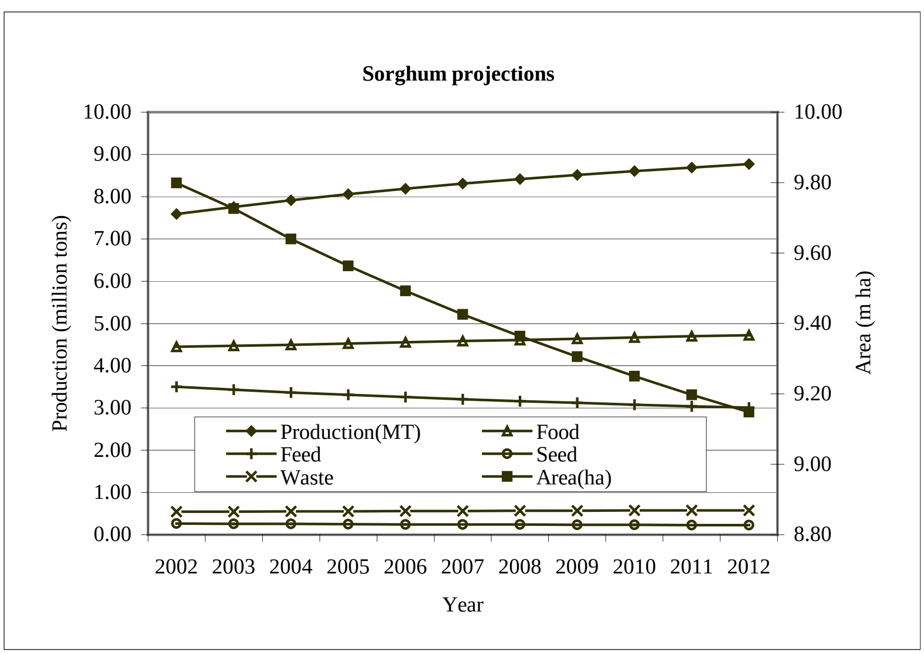


Figure 5.3 Production and use of bajra in the coming decade

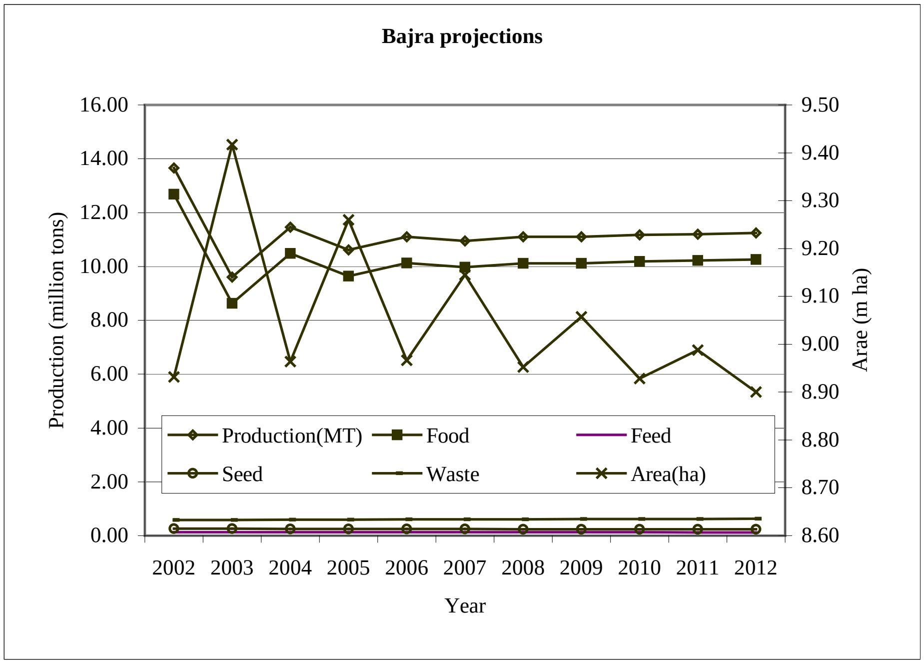


Figure 5.4 Production and use of barley in the coming decade

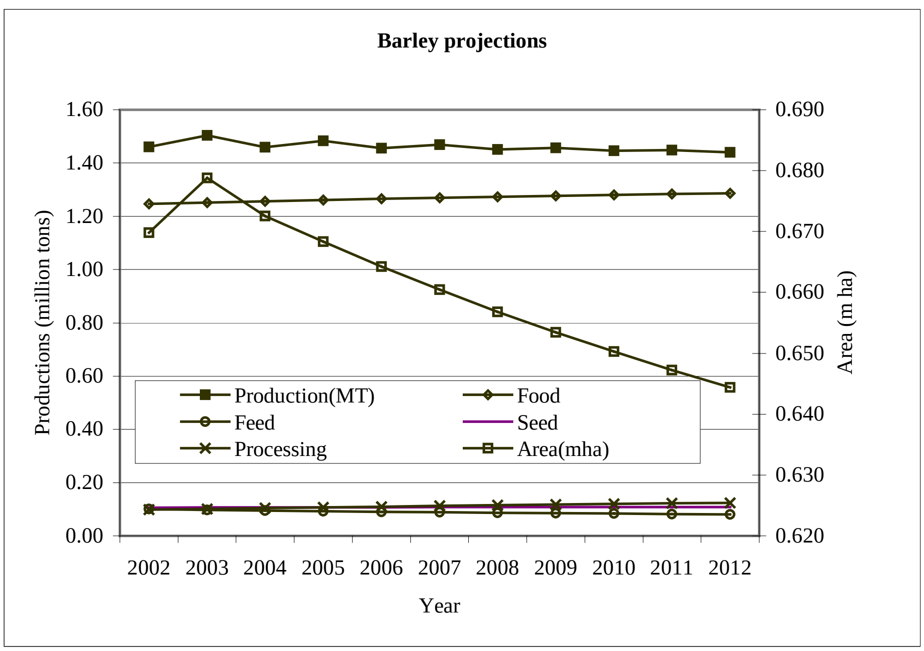
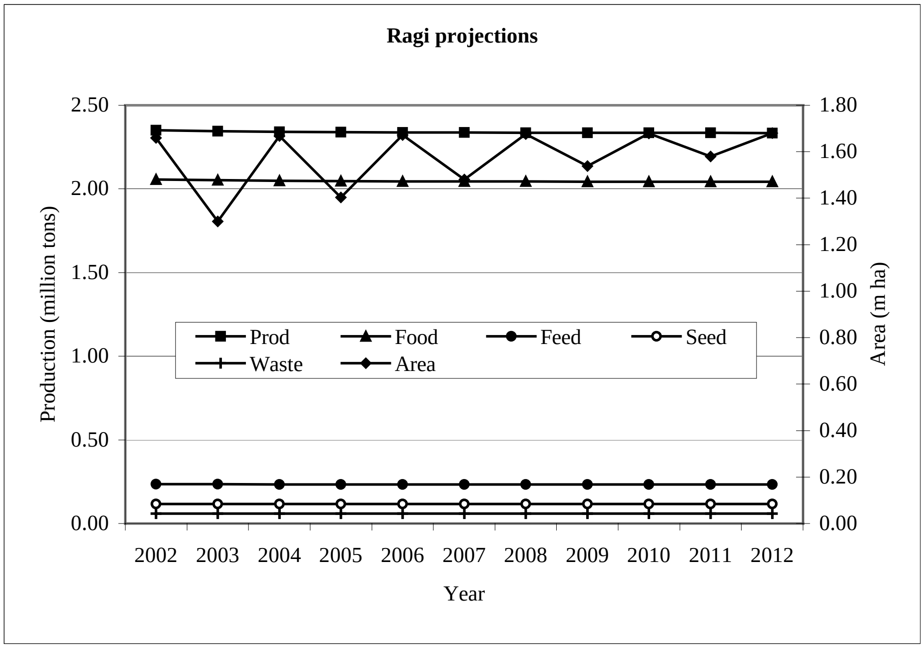


Figure 5.5 Production and use of ragi in the coming decade



5.4 Production response to market forces

Before discussing the case of coarse cereals, we should try to understand the habitat requirement of these crops, climate preference, soil type, availability of irrigation and other inputs. The high rate of variance in productivity of coarse cereals is yet another factor determining its increase/decrease in acreage. However, it is more interesting to consider the market wholesale price index and the minimum support price offered by the government (Table 5.1). The market price for coarse cereals is higher compared to the support price but the uncertainty of the market behaviour/trends does not attract farmers to take the risk compared to crops like paddy and wheat. During 2002, due to drought, production has been affected and the market prices are 40 per cent more than the previous year. Changes in land use and land cover due to increasing sources of irrigation and urbanization/projects also determine crop choice. The present emphasis on crop and land use diversification has a potential for boosting the production of these crops if the market and the processing industry are supportive. Crop zonation and policy are important to steer the desired change. It is again emphasized that these crops with their potentials should attract the attention of planners.

Table 5.1 Minimum support price and market wholesale price (Rs/100 kg) of commodities in 2000-2001

Price	Paddy	Wheat	Barley	Maize	Bajra	Sorghum	Ragi
Market price	530	725	800	720	600	700	750
Support price	510	620	450	445	445	445	445

5.5 Development of production technology

There are certain key points for higher productivity of coarse cereals:

- Selection of improved, high yielding varieties suitable for specific soil and moisture conditions.
- Use of proper sowing time and planting geometry. Use of seed drills for line sowing and proper seed rate. Treating the seed with fungicides before sowing. In heavy rainfall areas transplant using 20 day old seedlings. Assure the use of biofertilizers i.e. 3 g Azospirillum per kg seed at the sowing time. Apply recommended fertilizer doses. Irrigate the crop at critical stages of water stress.
- Keep the plot weed free. Apply thinning 20 days after sowing. One to two interculturing and one hand weeding 30-35 days after of sowing.
- With changing farming systems and cropping sequences, specific technologies would be required to assure high productivity. The institutions outlined elsewhere have a system of regular research and technology dissemination to upscale farming skills and productivity.

5.6 Production projection

While the productivity of most of the coarse cereals has shown similar changes compared to rice and wheat, area has been declining under most of these crops except maize. The only scope for their growth is through high-level research and input development. The percentage change in productivity between 1990-1991 and 2000–2001 of most of these crops shows that for ragi and barley the change has been more than for paddy and wheat but still the production of these crops has not increased because of the decline in acreage. It is expected that by the use of hybrid technology, grain production can be enhanced in the case of maize and sorghum. These two crops have the potential for meeting the increased demand. Barley as a crop needs emphasis in the farming systems for it has the potential utilization to meet the demand of industry and also livestock production as a feed crop. The Technology Mission on Coarse Cereals may further accelerate its production prospects. Summer sorghum production is yet another area for expansion.

The emphasis on proper land use and water conservation now being given may support the crops more suited for the degraded lands and poor soils with a lesser irrigation water requirement. Under such a policy initiative coarse cereals have a future.

6. Measures for Closing the Supply and Demand Gap

6.1 Government and private company initiatives

6.1.1 Domestic production reduction and expansion

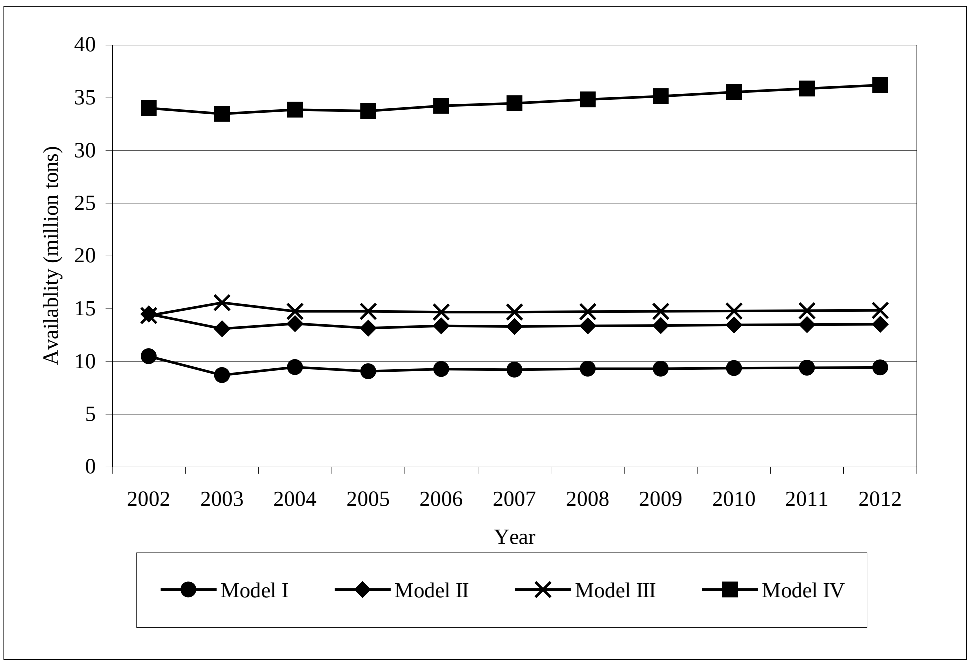
The present level of requirement of animal feeds is estimated at 114.35 million tons for all species of livestock including poultry and is increasing at a rate of 2.62 per cent. The present level of production as per Planning Commission discussion papers (2001) is 41.96 million tons thus showing a deficit of 64.27 per cent. This gap is likely to continue. In another estimate, Taneja (1999) has shown a 47 per cent shortage of concentrates. He also stated that "grains and concentrates contribute only to the tune of 3 per cent in the total feed resources in the country and only lactating animals receive better feeding through the supplementation of by-product concentrates (oilcake, bran, chunnies etc.). Sheep and goats are generally maintained on grazing and browsing and no concentrates are fed. Farmers neither have knowledge of nor feed their livestock as per nutrient requirements. The present level of availability of 42 million tons of raw material is processed and made available to the livestock industry. It is also estimated that of this availability, 25 per cent is milled as compound feed and the rest fed as such to the animals by the farmers." In India, annual production of compound feed by CLFMA members is around 3.2 million tons while the unorganized sector and cooperatives account for around 4-5 million tons. The feed industry also feels that with the increasing potential in the poultry and dairy sector, the future demand for compounded feed is expected to grow at 12 per cent per annum.

With growing concerns for quality animals and high productivity, feed use is likely to increase. It is, therefore, estimated for 2002, the total feed requirement to be 114.35 million tons while production is only 67.55 m. Thus, about a 40.93 per cent deficit is projected at the present level of production. Farmers in rural households manage the deficit by use of other grains like wheat and broken rice including kitchen waste for feeding the productive animals. The National Dairy Development Board and Indian Dairy Corporation are making efforts to increase the level of production of milk and also the animal feeds to support them. Many state dairy corporations and the milk societies also make efforts to provide feeds to the members. While such efforts have supported the white revolution in India, they are also likely to improve the concept of animal nutrition and proper feeding of the livestock. Dairy production in India has become relatively organized in some parts of the country but meat production is still unorganized and dispersed. It is due to this reason that the estimates of demand and supply are based on population trends.

Based on the projected output of different coarse cereals, four types of option have been proposed. The first option contains the feed constituents in light of Planning Commission recommendations (maize 20 per cent, barley 10 per cent, sorghum 10 per cent, bajra 50 per cent and ragi 10 per cent). The second option contains 52 per cent maize of the production projection and the other feed constituents as per option I. The third option comprises of the rest of the coarse cereals out of total production of each cereal minus the food use of the concerned crop (in the case of sorghum 39.1 per cent production is assumed to be used for livestock feed) and the final option is the same as option three but added with all cereals. These four options were tried both with exceptionally coarse cereals and all the cereals (Figures 6.1 and 6.2). It was found that the fourth option could provide 34.00 to 38.159 million tons of feed available for livestock consumption. Feed resource availability in the form of oil seed cakes (18.4 million tons) amounted to total feed availability for livestock consumption at 54.48 million tons. Other supplies through non-edible oil cakes (11.0 million tons) make it possible to raise the feed availability to 65.48 million tons. When all the coarse cereals and chunnies are added, the average feed projection for the coming ten years would be 34.67 million tons and after augmentation with the oil cakes (18.4 million tons) and non-edible oil cakes (11.0 million tons) the available feed resource for livestock for the coming decade will be 64.07 million tons. Thus, the availability continues to be short by 43.99 per cent of the requirement. Considering the 35 per cent poultry and the majority of dairy production in rural households, it appears that the nutritional needs are being met from other domestic sources (tapioca, turnip, carrots, kitchen waste, etc.). So the remaining options are:

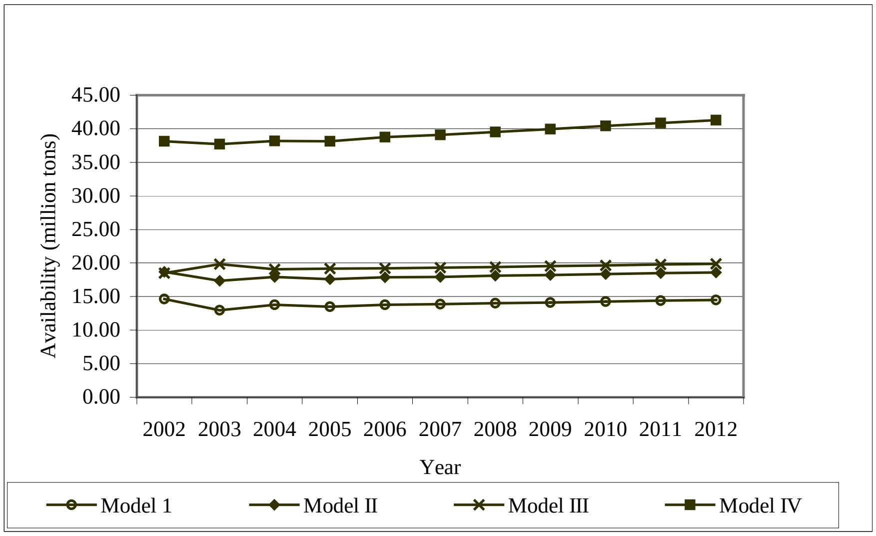
- To encourage the production of coarse cereals.
- To emphasize the promotion of oil seed and pulse crops to add to the production of chunnies and cake which is expected to ease the situation.

Figure 6.1 Feed availability projections for India based on coarse cereals



Source: Author's calculation.

Figure 6.2 Feed availability projections for India based on all cereals



- To encourage growing of nutritious green fodders, specially legumes to meet the increasing protein requirement in the animal diet. Making leucerne/stylo leaf meal during the period of high production for dry months can help reduce the use of food grains/coarse cereals in the feed.
- To improve the grazing systems to sustain more livestock through participatory mode. Encourage legume cropping / legume seeding in the degraded lands to meet the nutritional needs of the livestock.
- To manage agrosilvopastoral systems to develop a balance sheet approach for meeting the demand of the green fodder, dry roughages, concentrates and seasonal grazing to meet the challenges of dry climates and over utilization of natural resources.

6.1.2 Research and development

6.1.2.1 Upstream

The Indian Council of Agricultural Research, New Delhi, has a number of institutes to address research on each of these crops. The institutes mentioned below regularly update their mandate and adjust their working as per government policies to achieve the desired targets.

Commodity	Research Institute involved
Maize	Directorate of Maize Research, IARI Campus, Pusa, New Delhi
Sorghum	National Research Centre for Sorghum, Hyderabad
Barley	AICRP on Barley Improvement, DWR Karnal
Sorghum	AICRP on Sorghum Improvement, Hyderabad
Millets (Ragi)	AIC Small Millets Improvement Project, UAS, Bangalore
Maize	AICRP on Maize, DMR, New Delhi
Pearl millet	AICRP on Pearl Millet, RAU, Jodhpur
Coarse cereals	AICRP on Under Utilized Crops, New Delhi
All fodder crops	Department of Forage Research in many agricultural universities work on almost all the crops of regional interest.

6.1.2.2 Downstream

Besides those at the central government and state government levels there are Directorates of Minor Millets Development. These crops are also researched in the State Agricultural Universities in different states. The Zonal Agricultural Research Stations under the

State Agricultural Universities also provide region specific research backup on these crops. The growing poultry industry in the organized sector and also pigery will demand maize grain and also millet, which has a larger scope in times to come. Since these often come under the organized sector as industry, the research and development support is expected to accelerate the growth and productivity of CGPRT crops.

6.1.2.3 International trade

The sustainability of coarse cereals in the agricultural economy of the country is speculated to depend largely on increasing capital intensity and export potential for competitiveness in the agricultural market of the country and the world. To put it another way, linkage to the world export market makes this sector more competitive and sustainable and lifts it out of the condition of stagnation of production.

During the past decade, sorghum and pearl millet have shown a consistent export performance whereas the performance of maize, barley, ragi and cereals have only picked up from the years 1993, 1995, 1992 and 1992 respectively. Even though the percentage share of total coarse cereal exports in the total export performance of the country over the years has not been significant, it can not be denied that the export of coarse cereals in absolute terms recorded an increasing growth over the period.

6.2 Farmer participation in feed crop development

6.2.1 Feed crop farming

6.2.1.1 Potentials

Most of the feed crops are grown under subsistence farming conditions on the dry lands that are dependent upon the monsoon rains. The soil conditions are mostly degraded and on marginal agricultural lands. Thus, they are subjected to the vagaries of the monsoon and also poor soil fertility conditions. These soils also suffer due to micronutrient deficiencies which limit production. Maize is an exception since it also covers highly productive lands in the upper Gangetic alluvial plains. Looking to the growing demand for feed crops and also their use as nutri-cereals in the diet of human beings, the growth potential is very high. In the case of maize, the growth is phenomenal and the productivity of the winter maize is more than 2 fold that of the kharif maize. The increasing emphasis with vibrant market support is likely to upscale its area and productivity. Based on this and the feed structure, the availability scenarios have been tested (Figures 6.1 and 6.2). As per the guidelines of the government's policy, 20 per cent of the maize + 10 per cent barley + 10 per cent sorghum + 10 per cent bajra and 10 per cent ragi are used as feed. Currently the use of maize in the poultry ration has increased and thus, 52 per cent of all maize production goes for feed. Eighty per cent of the kharif production of sorghum is utilized for feed (39.1 per cent of the total production). Based on these assumptions the availability has been calculated and presented in Figures 6.1 and 6.2. It shows that it is possible to produce 34.00 million tons of feed from the cereals during 2002. Considering the other factors of feed requirements for the livestock population already mentioned, it may be possible to meet the demand which is about 66 million tons annually (considering that dry animals and the small ruminants are not being provided with any concentrates). However, the requirements for increased livestock productivity will demand better nutrition for which efforts have to be continued.

6.2.1.2 Constraints

Farming technology is still very primitive and the lack of improved varieties are major constraints in many coarse cereal growing areas. The cropping systems and crop mixtures to support high production are not known to farmers. The uncertain environmental conditions and lack of contingency planning for these crops are also major constraints as is the poorly developed market, lack of a support price, cultivation and processing mechanization. These crops deserve special treatment since the area under them is decreasing in response to highly productive crops and also the increase in better inputs including irrigation.

6.2.1.3 Advantages

These crops are low input requiring and therefore, they can still be cultivated with a small initial investment. The low rainfall, poor fertility, bad soil conditions and uncertain monsoons can make it advantageous to grow these crops. Their increased production can also support better nutrition for both humans and livestock. The growing emphasis on nutri-cereals may bring further advantages to the farmers. Alternate uses for sorghum and other millets can also diversify the market and assure better market prices for these commodities. In organic farming and low input agriculture these crops are of great advantage to the farmer. The productivity advantage over maize and barley gives potential for their extended use in fragile agricultural zones.

6.2.1.4 Problems

Proper policy instruments for the development of the market and support for the farmers are the major problems facing the farmers. The slow growth of research outputs for the development of high yielding varieties in some of these crops is yet another problem as well as the identification of crop zones and their strict implementation in the field which should attract the attention of policy makers.

6.2.2 Response to market development

A market network system is the key issue in the use of feeds for livestock production. Unorganized milk marketing leaves farmers at the crossroads where they search for cheaper alternatives viz. *Stylo* leaf meal/*Leucaena* leaf meal or the bulk of green fodder to supplement the feed needs. Firmness in market prices has to be assured for making these crops more remunerative to the farmer. Support prices for these grains would be desirable to maintain the interest of farmers. At the same time, the organized marketing of animal products will be required. Import restrictions to safeguard the interest of coarse cereal growers in the country are important. If the customs duty on imports of these crops is raised, domestic market prices can be controlled and undesirable imports can be reduced. Thus, the proper execution of market intervention mechanisms in consonance with administered, market support prices (MSP) with respect to coarse cereals on par with wheat, rice, pulses, oil seeds, cotton and jute is a must to help provide a better market and also promote production growth to the farmers.

6.2.3 Response to manufacturing development

Taneja (1998) stated that despite a total availability of feeds of 42 million tons, the installed capacity of the feed mills is only 17.7 million tons processing about 10.7 million tons in the organized sector and 7 million tons in the unorganized sector. In the organized sector, members of the Compound Livestock Feed Manfactuer’s Association (CLFMA) and Co-operative Feed Miling Plants are manufacturing animal feed. There are 18 feed manufacturers in the fold of CLFMA membership with about 184 feed mills with an installed capacity of 5.1 million tons/yr. However, actual annual production is 3.2 million tons. There are another 100 - 200 unregistered feed plants producing 2.5 million tons, although they do not meet the conditions of nutrition security and standards. Considering the growing needs of the livestock industry, other cooperative factories manufacture 4-5 million tons of balanced concentrates. Other units manufacture about 2.5 million tons of feed. The future demand for feed milling will grow at an annual rate of 12 per cent. If this growth is encouraged, the production sector can be assured of a remunerative price. This has been observed in the state of Gujarat for crops like groundnut and coarse cereals. The processing of some of these crops as human food is also attracting higher production emphasis.

6.2.4 SWOT analysis

In the case of coarse cereals the strengths, weaknesses, opportunities and threats are as follows:

Strengths

- Large livestock population and good growth rate.
- Large area still under rainfed farming and drylands.
- Rising economy and growing emphasis on livestock products as opposed to food grains.
- Increasing demand for milk. Growth of peri-urban and organized dairy with cross-bred animals.
- Increasing demand for monogastric meat.
- Very high growth of the poultry sector (65 per cent organized and 35 per cent backyard in household setup) requiring coarse cereals for their optimum production.
- New hybrids of maize and sorghum with high yield potential.
- High productivity of winter maize in the north to meet the demands of crop diversification and also increased tonnage. Increasing area under rabi sorghum.

Weaknesses

- Livestock breeds are still not improved and rearing is mainly in households subsidiary to farming.
- The essential services for livestock improvement and health cover are weak.
- Product markets are poorly developed and uncertain.
- Policy support for feed crop farming and feed manufacturing is not appropriate.
- Low production capacity of feed industries and their location in only some zones of the country.
- Poor quality control by the unorganized feed manufacturers.
- Poor post harvest processing and handling systems.

Opportunities

- Promote exports of livestock products.
- Exports of coarse cereals as nutri-cereals and their processed products.
- Expansion of area under winter maize and sorghum.
- Strengthening soya product processing and meal production.
- Strengthening post harvest technology.

Threats

- Increasing emphasis on commercial crops may compete for area.
- Slow improvements in livestock productivity compared to world averages.
- Rising costs of raw materials affecting the economics of production and market growth of feeds.

7. Conclusions and Recommendations

Demand for coarse cereals in India has been falling with the exception of maize. The deflated or real price for the last two decades has been nearly stagnant for coarse cereals. These two facts indicate that the consumer is getting used to superior cereals. However, a class of consumers is sticking to coarse cereals and therefore, the price is stagnant as supply is adjusting to the demand. Production has kept pace with demand, despite the declining area under coarse cereals, mainly due to high-yielding varieties. The continued supply of high-yielding varieties helped reduce production costs and this helped coarse cereals (pearl millet) to be able to compete with cash crops like groundnut. World export prices (F.O.B.) are much cheaper than prices in India. The major use of coarse cereals in the world is for animal feed but in India for food. The above conclusions have led to the following policy needs:

- Promote coarse cereals for feed and other uses.
- In view of food security concerns, provide coarse cereals at subsidized rates to the poor otherwise the poor farmers and labourers will suffer most if supply declines and prices increase (Bapna, 2001).
- Most coarse cereals in developed economies are used for cattle feed. Variability in the production of coarse cereals is very high compared to fine cereals. Coarse cereals do not compete with wheat and rice. Farmers are motivated by profits and therefore, other crops such as pulses, cotton and vegetable crops compete for the scarce land. Demand of coarse cereals in India is shrinking with the exception of maize.
- Investment in R&D on these crops should increase. Greater investment is needed in the development of coarse cereal High Yielding Varieties (HYV) possessing resistance to drought and insect pests to reduce the cost of production and diversification of the cultivation of these crops in the areas rendered surplus.
- Negotiate with coarse cereal exporting countries under the WTO Agreement on Agriculture for a reduction in subsidies given by them to their farmers.
- Provision of supply of coarse cereals at subsidized rates to Below Poverty Line (BPL) families to ensure access to food as a measure of food security. Sorghum is grown for food, cattle fodder, feed and also provides raw materials for the manufacture of a wide range of industrial products.

Improving sorghum productivity

- Area under kharif sorghum has declined sharply, whereas area decline in rabi sorghum is comparatively slow. A wide range of High Yielding Varieties (HYVs) in sorghum have been bred to cater for the requirement of food, fodder, feed and industrial usages. Special HYVs of sorghum have been bred for forage. Improved sorghum production technology modules have been developed for different agro-climatic regions / sorghum based cropping systems through sustained research over the years. Community drier is a newly found and most eco-friendly integrated pest management (IPM) measure for the control of grain moulds in sorghum.
- Every part of the sorghum plant can be gainfully utilized for food and non-food usage. Moulded grain is preferred for the manufacture of potable alcohol. Sorghum malt, starch, alcohol, liquid glucose, High Fructose Syrup (HFS), malto-dextrins for use in the baking industry. Ethanol, jaggery and adjuncts need to be promoted on a large-scale.

- Check on sorghum trade through non-regulated markets by the Agriculture Produce Market Committees to ensure the payment of a legitimate market price to sorghum growers.
- Introduction of summer cultivation of sorghum to make the crop more competitive in terms of grain quality and productivity in India
- Large-scale popularization of inter-cropping of sorghum with pulses/oilseeds through incentives under development programmes.
- Introduction of sorghum cultivation in rice fallows.
- Sorghum is inherently produced through organic farming. Hence, suitable quality standards and the provision of a quality certification mechanism should be evolved for organically produced commodities as a measure of consumer preference and creating consumer awareness.
- Appropriate market intervention for the procurement of sorghum at administered prices should be ensured on par with wheat and rice.
- Emphasis on export of sorghum grain for cattle feed.
- Assured production of quality seeds of public bred sorghum cultivars.
- Effective quality control of sorghum seeds sold in the market.

Improving maize production

- Maize should be accorded special status and de-linked from coarse cereals for strategic development.
- The minimum support price of maize should be made more remunerative.
- Food subsidies on maize should also be provided like for wheat and rice on the supply of maize through PDS.
- Promotion of the cultivation of Quality Protein Maize (QPM) and single cross maize hybrids through Mission Mode approach.
- Enhancement of the Seed Replacement Rate (SRR) in maize by way of fast track seed production of High Yielding Varieties (HYV) of maize in the states of Bihar, Gujarat, Madhya Pradesh, Rajasthan and Uttar Pradesh, where the productivity of maize is less than the national average.
- Involvement of the Indian Maize Development Association (IMDA) in the strategic development of maize for encouraging “contractual farming in maize” and the export of value added products of maize.
- Renovation and upgrading of the machinery and capacity expansion of the existing “starch plants’ with appropriate fiscal support like Mission on Cotton.

Cultural and nutrient management

- Imbalance and inadequacy of fertilization on coarse cereals is omnipresent due to their inherent cultivation on the marginal and degraded soils.
- Deficiency of zinc, sulphur, boron, iron, manganese and copper has been recorded in Indian soils across the regions.
- Maize and barley are more susceptible to micro-nutrient deficiency, sorghum and pearl millet are moderately susceptible and ragi is least susceptible.
- Integrated use of 2.5 to 5.0 t/ha of farm yard manure (FYM) or City Compost supplements the zinc requirement by 25-50 per cent while 10-15 t/ha FYM is adequate to correct the micro-nutrient deficiency in coarse cereals.
- Coarse cereals do not respond to copper and molybdenum application in Indian conditions.
- Regular application of 20-30 kg/ha of sulphur before sowing significantly enhances the productivity of most of the coarse cereals.

- Diversification of agriculture should get priority in view of the decline in productivity due to depletion of ground water resources and the agenda of WTO on agriculture.
- Optimum use of micro-nutrients also ensures the quality of the produce as well as reduces the toxicity of trace elements like Selenium on forages on problem soils.
- Chelated sources of micro-nutrients are found to be twice as efficient as non-chelated inorganic fertilizers or equivalent zinc basis but chelated zinc sources are uneconomical.
- Multi micro-nutrient mixture use is to be restricted to certain crops with expert's recommendations to save extra costs and reduce heavy metal pollution in the soil and environment.

Post harvest management

- Adaption of coarse cereals to poor habitats and resources, and the lack of awareness of the food value of coarse cereals among urbanites/irrigated areas are responsible for the limited progress of these crops.
- All of the cereal grains are plant seeds and, as such, contain a large centrally located starchy endosperm encapsulated with hull, bran and embryo or germ usually near the bottom of the grain. Hull in grain is indigestible by man, bran, often being dark coloured, repels consumer preference, germ, being rich in oil is enzymatically active and sometimes produces rancidity under certain conditions. All need to be removed through post-harvest management.
- Development of coarse cereal based nutri-foods, particularly for the urban population by ICAR/CFTRI/private sector food companies. Development of improved mills for milling of coarse cereals.
- Research on storage and enhanced shelf-life of coarse cereals.
- Research on eco-friendly packaging technology for coarse cereal products.
- Starchy and proteinous endosperm of grains offer food value which is achieved by proper milling and pre-milling operations and proper post-harvest management and are crucial to improve food value and nutritional aspects as well as induce trade competitiveness in the commodity.

Environmental issues and crop diversification

- Coarse cereal cultivation is confined to arid and semi-arid regions across the globe. An arid climate is characteristic of low rainfall, high summer temperatures with very low winter temperatures associated with high wind velocity and high evapo-transpiration.
- A high tree canopy with a perennial grass canopy on the soil surface neutralizes the harshness of the climate and creates ecological equilibrium for the survival of living beings. Multi-purpose trees are an integral part of arid and semi-arid farming systems and the livelihood of the people of these regions. Cyclic droughts often occur in arid and semi-arid regions. Improvements in pearl millet productivity are crucial in the arid districts namely; Bikaner, Barmer and Jaisalmer of Rajasthan and this could be achieved to the level of the productivity of pearl millet in East Rajasthan with plausible diversification of this area by introducing novel agroforestry systems. Research is needed for creating competitiveness among coarse cereals. Development of integrated pest management (IPM) modules for coarse cereals with greater emphasis on cultural practices is also needed.
- Agroforestry based farming systems in these areas hold promise for crop productivity and environmental sustainability besides assuring high economic outputs to the farmer.

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Appendices

Appendix Table 1 Proposed average feeding rate of concentrates to different categories of livestock

Species	Daily rate of feeding conc. Mix. (kg)	Requirement/head/year (million tons)
Cattle, cross bred		
Milch cow (8 kg)	3.0	1.10
Dry cow	1.0	0.37
Not calved cow	1.0	0.37
Adult males	0.5	0.18
Calves	1.5	0.55
Improved cattle (Indigenous)		
Milch cow (4 kg)	2.0	0.73
Dry cow	0.5	0.18
Not calved cow	0.5	0.18
Male	1.5	0.55
Adult calf	0.5	0.187
Other deshi		
Milch cow (2 kg)	0.5	0.18
Dry cow	0.0	0.18
Not calved cow	0.5	0.18
Adult male	0.5	0.18
Calves	0.5	0.18
Buffaloes		
Improved milch (6 kg)	3.0	1.10
Others milch (3 kg)	1.0	0.37
Males and young and other females	1.0	0.37
Sheep		
Improved	0.275	0.10
Others	-	-
Goats		
Improved	0.275	0.10
Others	-	-
Pigs		
Improved	2.50	0.91
Others	-	-
Equines and camels		
Improved	3.00	1.10
Others	0.25	0.09
Poultry		
Improved Layers	0.110	0.040
Improved bringers	0.060	0.022

Appendix Table 2 Different categories of livestock in each species in the year 2002-2003 (Planning Commission Report, 2001)

Species/Types	2002-03
CATTLE	
1. Cross bred	
(i) Milch cow	
(ii) Dry cow	2.78
(iii) Not calved cow	0.96
(iv) Total cow	10.35
(v) Males	5.65
(vi) Calves	9.99
Grand Total	25.99
2. Improved (Indigenous)	
(i) Milch cow	8.15
(ii) Dry cow	3.43
(iii) Not calved cow	1.19
(iv) Total cow	12.77
(v) Males	6.96
(vi) Calves	12.32
Grand Total	32.05
3. Other deshi	
(i) Milch cow	23.45
(ii) Dry cow	21.80
(iii) Not calved cow	3.85
(iv) Total cow	49.10
(v) Males	62.87
(vi) Calves	50.98
Grand Total	162.95
Total (1 + 2 + 3)	220.99
BUFFALO	
1. Improved milch	9.41
2. Others, milch	30.79
3. Males and young and other females	56.31
Total	96.51
SHEEP	
1. Improved	1.33
2. Others	70.99
Total	72.32
GOATS	
1. Improved	1.11
2. Others	122.49
Total	123.60
PIGS	
1. Improved	1.62
2. Others	15.39
Total	17.01
EQUINES, CAMELS	
1. Improved	0.56
2. Others	70.74
Total	4.62
POULTRY	
1. Improved	67.58
2. Others	70.74
Total	

Appendix Table 3 Potential important varieties of different coarse cereals in India

Sorghum varieties

S.No.	Grain type	Area	Grain yield (X100 (kg/ha)
1.	CSH 13 R (hyb)	Rabi (All India)	31.0
2.	CSH-1 (hyb)	Rabi/Khariff (All India)	30-40
	CSH-2 (hyb)	Rabi/Khariff (All India)	30-40
	CSH-3 (hyb)	Rabi/Khariff (All India)	30-40
	CSH-4 (hyb)	Rabi/Khariff (All India)	30-40
	CSH-5 (hyb)	Rabi/Khariff (All India)	30-40
	CSH-6 (hyb)	Rabi/Khariff (All India)	30-40
3.	Gujrat Jowar-35	(Gujrat area)	35-40
	Gujrat Jowar-36	(Gujrat area)	35-40
4.	SPH-20 (hyb)	Maharashtra	40-50
5.	SPV-462	Tamil Nadu	35-50
6.	N-14	Rabi (AP)	31-36
	N-2	Rabi (AP)	31-36
7.	CSH-13R (hyb)	Rabi (All India)	31
8.	PVK-400 (Panchali)	All India heavy soil	40-45
9.	GJ-38	Zone I, II & III	30
10.	SPH-468 (hyb)	Maharashtra (Kharif)	42-45
	SPH-388 (hyb)	Maharashtra (Kharif)	42-45

Forage

S.No.	Grain type	Area	GFY(X100 kg/ha)
1.	PC-6	Whole country single cut	35-50
	PC-9	Whole country single cut	35-50
	PC-23	Whole country single cut	35-50
2.	HC-171	Single cut	40-50
	HC-260	Single cut	40-50
3.	UP Chari-1	U.P., Maharastra	35-45
	UP Chari-2	Tamil Nadu	35-45
	Pant Chari-3	Single cut	35-45
4.	HC-136	Whole country single cut	37-50
5.	Raj Chari-1	Single cut long duration	37-50
	Raj Chari-2	Single cut long duration	37-50
6.	CO-27	Double cut Tamil Nadu	45-65
7.	AS-16	Double cut Gujrat	45-65
8.	SSG-988	Multi cut whole country	75-105
	SSG-898	Multi cut whole country	75-105
	SSG-855	Multi cut whole country	75-105
9.	Hara Sona	Multi cut whole country	80-110
	SPH-388 (hyb)	Maharashtra (Kharif)	42-45

Maize

Variety name	Area of adaptability	Conditions
Hybrids	Khariff season	
*Ganga-1	Punjab, Haryana, Uttar Pradesh, Delhi, Bihar, West Bengal and parts of Madhy Pradesh	Rainfed
*Ganga-101	Punjab, Haryana, Delhi, Uttar Pradesh, Bihar, West Bengal, Orissa and parts of Madhya Pradesh	Irrigated and rainfed
Deccan	Karnataka, Tamil Nadu and Andhra Pradesh	Well distributed rainfed areas
Ranjit	Northwestern plains	Rainfed and irrigated
VL-54	Hilly region of the Himalayas	Rainfed
Ganga Safed-2	Punjab, Haryana, Delhi, Uttar Pradesh, Bihar and West Bengal	Irrigated and rainfed
Hi-starch	All over India where starch factories exist. Most popular in Bihar (Darbhanga, Muzaffarpur, Mothihari and Champaran and Shahabad Distt)	Irrigated
*Ganga-3	Punjab, Haryana, Delhi, parts of Rajasthan, Uttar Pradesh, Bihar and West Bengal	Irrigated and rainfed
Himalayan-123	Valleys of Kashmir, Punjab hills and Himachal Pradesh	Irrigated and rainfed
Ganga-4	Madhya Pradesh, Bihar and Tarai areas of Uttar Pradesh	Rainfed and irrigated
Ganga-5	Punjab, Haryana, Delhi, Uttar Pradesh, Bihar and West Bengal	Rainfed
Ganga-9	Punjab, Haryana, Uttar Pradesh and Bihar	Irrigated and rainfed
Composites	Himalayan hills up to 1700-1800 metres altitude and peninusular India (Andhra Pradesh, Karnataka and Tamil Nadu)	
Amber		
Vijay	Punjab, Haryana, Delhi, Uttar Pradesh and Bihar	Rainfed
Sona	Punjab, Haryana, Delhi, Uttar Pradesh, Bihar and West Bengal	Rainfed and irrigated
Kissan	Punjab, Haryana, Uttar Pradesh, Delhi, Bihar and West Bengal	Rainfed and irrigated
Vikram	Punjab, Haryana, Delhi, Bihar, and West Bengal, low rainfall areas of Rajasthan, Gujarat and Punjab	Rainfed and irrigated
Jawahar	Punjab, parts of Rajasthan, Uttar Pradesh, Delhi and Bihar	Rainfed and irrigated
High lysine composites		
Protina	Karnataka and Tarai areas of Uttar Pradesh	Rainfed and irrigated
Shakti	Madhya Pradesh, Rajasthan and their Tarai areas	Rainfed and irrigated
Rattan	Punjab and Rajasthan	Rainfed and irrigated
	High yielding hybrids and composites for rabi and summer	
Hybrid		
Hi-starch	North Bihar as well as where starch industries exist. It can be grown in other white maize-growing areas of the country. It has high starch recovery.	Irrigated
Ganga-4	North Bihar in rabi and Taria belt in summer	Irrigated
Ganga-2	A very popular hybrid grown in kharif as well as rabi throughout the country	Irrigated
Ganga-5	All parts of the country particularly Andhra Pradesh, Maharashtra, Karnataka and Tamil Nadu.	Irrigated
Decan	Popular in peninsular India. Particularly Andhra Pradesh, Karnataka and Tamil Nadu.	
Composite varieties		
Vijay	Recommended for all state of peninsular India	Irrigated
Kissan	Peninsular India as well as eastern states	Irrigated
Shakti	All rabi maize areas of the country	
Protina	Karnataka and the tarai belt of Uttar Pradesh	

* Withdrawn from cultivation.

Bajra (Pearl millet)

Variety name	Area of adaptability	Conditions	GFY(X100 kg/ha)
Hybrid bajra-1 (23A X Bii 3B)	Under rainfed and irrigated conditions in all bajra growing states	75-90 days for maturity, susceptible to downy mildew and ergot	35-40
Hybrid bajra-2 (23A X J 88)	Madhya Pradesh, Gujarat, Kutch and adjacent areas in Rajasthan	75-90 days for maturity, poor yield ability, now out of cultivation	35-40
Hybrid bajra-3 (23A X J 104)	Low rainfall and light soil areas of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana	75-80 days for maturity, higher protein content than Hy. Bajra-1.	35-40
Hybrid bajra-4 (23A X K 560)	All bajra growing states except Punjab. Due to problem of diseases it is restricted to Andhra Pradesh and Karnataka.	Maturity in 95 days. Suited to rainfed and irrigated conditions, high susceptibility to downy mildew and ergot. Now out of cultivation.	35-40
Hybrid bajra-5	All bajra growing states under rainfed and irrigated conditions.	92 days to maturity, grains attractive and bold. Moderate resistence to downy mildew and ergot.	35-40
PHB-10 (1975)	All bajra growing states. Highly adapted to irrigated and rainfed situations.	Maturity in 88 days. Resistent to downy mildew but susceptible to ergot and rust.	35-40
PHB-14 (1975)	All bajra growing areas of the country. Highly adapted to rainfed and irrigated conditions.	Maturity in 87 days. Resistant to downy mildew but susceptible to ergot and rust.	35-40
BJ-104 (514A X 5104), BK560 – 230 (5141A X K 560-230)	Latest hybrids of bajra developed at IARI. Suited to rainfed and irrigated situations.	Maturity in 75-85 days. Resistant to downy mildew and gaining popularity among the farmers of bajra growing states.	35-40

Barley

Variety name	Area of adaptability	Conditions
A. Plans		
Ratna	Rainfed areas of eastern Uttar Pradesh, Bihar, West Bengal	Highly tolerant to saline alkaline soil conditions
RS-6	Irrigated and rainfed areas of central and eastern Rajasthan, and northern Madhya Pradesh	(i) Highly tolerant to saline conditions. (ii) Low protein content and good for malt and brewing.
Jyoti	Irrigated areas of Haryana, Punjab, Uttar Pradesh, Delhi, northern Rajasthan.	Process wide adaptation under irrigated conditions
RDB-1	Irrigated areas of Rajasthan only	Semi-dwarf, capable of giving 30 to 35 q/ha on 50-60 kg N/ha application
RD-31	Irrigated and rainfed conditions in northern part of Rajasthan	Semi-dwarf and gives 35 quintals grain yield per hectare under good management conditions
RD-57	Irrigated conditions in southeast Rajasthan and M.P.	Semi-dwarf high yielding variety
*Vijaya	Rainfed areas of western U.P., Delhi and M.P.	Early in maturity
*K-24	Late-sown conditions in east U.P.	Early in maturity
*Azad (K-125)	Rainfed conditions in eastern U.P., Bihar and West Bengal	Highly responsive to the management practice

Continued……….

Barley (continued)

Variety name	Area of adaptability	Conditions
B. Hills		
Kailash	Rainfed areas of medium to low elevation of H.P. and U.P. hills	Resistant to yellow rust
*Himani	Rainfed areas of medium to low elevation of H.P. and U.P. hills	Matures about a week earlier than Kailashi, resistant to yellow rust
*Dolma	Rainfed areas of medium to high elevation of H.P. and U.P. hills	Resistant to yellow rust
*BG-25	Irrigated, timely sown conditions	Haryana
*BG-108 and *RD-118	Irrigated, late sown conditions	Haryana
C-164	Irrigated areas of Punjab and Haryana	Resistant to yellow rust in the adult plant stage
K-70	Flooded areas of Uttar Pradesh	
'Amber' (K71)	Rainfed areas of eastern Uttar Pradesh	
BR-32	Bihar	
NP-113	Delhi	

*Released by State.

Barley

Barley varieties for different areas

Variety	Year of release/pre-release	Areas of adaption	Special characteristics
		(A) NORTH-WESTERN PLAINS	
(i) Suitability for irrigated, timely-sown conditions			
Jyoti	1970	Punjab, Haryana, Delhi, plains of Jammu and Kashmir; western U.P., northern Rajasthan	Medium tall; possesses wide adaptation to restricted irrigated conditions
RDB-1	1971	Rajasthan only	Semi-dwarf; capable of giving 45-55 q per ha with 50-60 kg of N per ha
Clipper	1973*	Pre-released for the Gurgaon district and its adjoining areas	Medium in height, 2-rowed, suitable for malting and brewing; resistant to yellow rust in the adult-plant stage
BG 25	1974*	Haryana, Delhi, western U.P. and northern Rajasthan. Released in Hayayan in 1975	Medium tall
Ranjit (DL70)	1975*	Punjab and plains of Jammu and Kashmir. Released in Punjab in 1974	Semi-dwarf and stiff strawed; resistant to yellow rust; early in maturity, capable of give 45-55 q/ha with 50-60 kg N/ha
RD-103	1976*	Northeastern Rajasthan, excluding areas where yellow rust is a serious disease. Also showing promise in Karnataka	Semi-dwarf; capable of giving 45-55 q/ha with 50-60 kg N/ha
(ii) Suitability for irrigated, late-sown conditions			
BG 108	1974*	Jammu, Punjab, Haryana, Delhi, northern Rajasthan	Medium-tall; resistant to yellow rust in the adult plant stage
RD 118	1974*	Jammu, Punjab, Haryana, Delhi, northern Rajasthan	Medium-tall
BG 105	1975	Haryana	Medium-tall; resistant to yellow rust in the adult plant stage
DL 88	1976*	J Jammu, Punjab, Haryana, Delhi, northern Rajasthan	Medium in height, resistant to yellow rust in the adult-plant stage

Continued……….

Barley varieties for different areas (continued)

Variety	Year of release/pre-release	Areas of adaption	Special characteristics
(A) NORTH-WESTERN PLAINS			
(iii) Suitability for rainfed conditions			
Vijay	1972	Western Uttar Pradesh	Medium-tall
DL 3	1973*	Delhi, northern Rajasthan, Haryana and western U.P. Also showing promise in peninsular zone	Medium-tall
RD 31	193*	Delhi, northern Rajasthan, Haryana and western Uttar Pradesh	Medium-tall
PL 56	1975*	Punjab, Jammu and Dhra Dun Valley. Released in the Punjab State in 1975	Resistant to yellow rust in the adult-plant stage
(B) NORTH-EASTERN PLAINS			
(i) Suitability for irrigated, timely-sown conditions			
Jyoti	1970	Easter U.P., Bihar and West Bengal	
DL 36	1974*	Eastern U.P., Bihar and West Bengal. Also showing promise in the peninsular region	Medium-tall; fairly good straw; tolerant of yellow rust and aphids
(ii) Suitability for rainfed conditions			
Ratna	1970	Eastern Uttar Pradesh, Bihar and West Bengal. Also showing promise in the coastal areas of Sunderban and in the peninsular zone	Medium-tall; possesses wide adaptation to rainfall condition; highly tolerant to saline conditions
Azad	1974	Eastern Uttar Pradesh, Bihar and West Bengal. Released in U.P. in 1975. Showing promise in the peninsular zone	Medium-tall
(C) CENTRAL PLAINS			
(i) Suitability for irrigated, timely-sown conditions			
R.S. 6	1970	Southern Rajasthan, northern M.P. and southern U.P.	Medium-tall; highly tolerant to saline conditions; low in protein content and good for malting and brewing
R.D. 57	1974*	Southern Rajasthan, northern M.P. and southern U.P.	Medium-tall
(ii) Suitability for rainfed conditions			
R.S. 6	1970	Southern Rajasthan, northern M.P. and southern U.P.	Resistant to yellow rust; matures about a week earlier than 'Kailash'
Dolma	1974	Medium to high altitudes of Himachal Pradesh where hull less barley is under cultivation. Under tests in the hills of U.P. and Ladakh	Resistant to yellow rust; hull less grains; high protein content

* Pre-released by the All-India Barley Research Workers' Workshops.

Barley varieties and their production potential in different zones/production conditions

Variety	Zone	Production condition	Mean yield (t/ha)		Potential yield (t/ha)	
			2001-02	3 year mean	2001-02	3 year best yield
K560	NEPZ	RF(TS)	3.33	2.96	3.50	3.90
K603	NEPZ	RF(TS)	3.39	3.13	3.53	3.76
LAKHAN	NEPZ	RF(TS)	3.30	3.01	3.57	4.18
RD2508	NWPZ	RF(TS)	2.06	2.82	2.83	3.70
HBL276(Huskless)	NHZ	RF(TS)	2.09	1.77	3.26	3.26
BHS352(Huskless)	NHZ	RF(TS)	2.33	2.19	3.86	3.86
HBL113(2 row)	NHZ	RF(TS)	2.84	2.58	4.59	4.59

Continued……….

Barley varieties and their production potential in different zones/production conditions (continued)

Variety	Zone	Production condition	Mean yield (t/ha)		Potential yield (t/ha)	
			2001-02	3 year mean	2001-02	3 year best yield
BHS169	NHZ	RF(TS)	2.56	2.57	4.35	4.35
RD2035	NWPZ	IR(TS)	3.80	4.12	4.47	5.35
RD2552	NWPZ	IR(TS)	3.98	4.40	4.78	5.53
JYOTI	NEPZ	IR(TS)	3.34	3.42	4.19	4.21
BCU73*(2-R)	NWPZ	IR(TS)	3.34	3.74	4.50	5.01
DWR28*(2-R)	NWPZ	IR(TS)	3.57	3.97	4.71	5.27
RD2503*	NWPZ	IR(TS)	3.71	3.95	4.91	5.71
K551*	NWPZ	IR(TS)	3.91	4.17	4.57	5.41

*Malt type barley varieties.

Recent barley varieties

Production condition	NWPZ	NEPZ	NHZ	PZ
Irrigated				
a) Timely sown	RD 2552, RD 2035, RD 2503, PL 426	RD 2503, RD 2552, K 508, K 551		
b) Late sown	RD 2508, DL 88	RD 2508, Manjula		-
Rainfed	RD 2508, K 560, PL 419	RD 2508, K 560, K 603 Gitanjali*	BHS 169, HBL 113, HBL 276*, HBL 316	-
Alkaline and Saline soils	RD 2552, DL 88	RD 2552, Azad, DL 88	-	-
Nematodes (Molya) affected soils	RD 2035, RD 2052	-	-	-
Malt Barley	BCU 73, ALFA 93	BCU 73, K 551	-	BCU 73, DL 88

*Huskless Varieties.

Appendix Table 4 Data-series of different coarse cereals (1991 to 2000)

	Farm produce prices (Indian Rs/100 Kg)					
Year	Paddy	Sorghum	Bajra	Maize	Ragi	Barley
1991	205	180	180	180	180	200
1992	230	205	205	210	205	210
1993	270	240	240	245	240	260
1994	310	260	260	265	260	275
1995	340	280	280	290	280	285
1996	360	300	300	310	300	295
1997	380	310	310	320	310	305
1998	415	360	360	360	360	350
1999	440	390	390	390	390	385
2000	490	415	415	415	415	430
2001	510	445	445	445	445	500
2002	530	485	485	485	485	500

	Feed consumption (million tons)				
Year	Maize	Bajra	Sorghum	Barley	Ragi
1991	5.018	0.117	5.044	0.196	1.228
1992	4.659	0.222	4.567	0.204	1.311
1993	4.191	0.124	3.167	0.181	1.491
1994	5.195	0.179	5.009	0.158	1.061
1995	4.992	0.135	4.461	0.100	1.407
1996	4.618	0.142	3.507	0.120	1.315
1997	4.956	0.135	3.648	0.130	1.211
1998	5.600	0.138	4.274	0.150	1.081
1999	5.626	0.133	2.944	0.140	1.082
2000	5.798	0.113	3.292	0.130	1.418

	Production (million tons)				
Year	Maize	Bajra	Sorghum	Barley	Ragi
1990	9.650	6.650	12.900	1.486	2.770
1991	8.960	6.890	11.680	1.632	2.340
1992	8.060	4.670	8.100	1.699	2.580
1993	9.990	8.880	12.810	1.512	2.530
1994	9.600	4.970	11.410	1.313	2.600
1995	8.880	7.160	8.970	1.283	2.340
1996	9.530	5.380	9.330	1.510	2.500
1997	10.770	7.870	10.930	1.462	2.350
1998	10.820	7.640	7.530	1.679	2.090
1999	11.150	6.960	8.420	1.538	2.810
2000	11.470	5.660	8.860	1.456	2.320